An Overview of Modern Global Illumination

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University of Minnesota Morris

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Light

An Overview of Modern Global Illumination

Let's talk about *light*.

Light

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What is Global Illumination?

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    - Animated Film Production (Pixar's *Monster's University*)

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  - Used in applications like...
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    - Computer Video Games (Tom Clancy's *The Division*)
    - Animated Film Production (Pixar's *Monster's University*)

    Let's look at some examples...

Examples of Global Illumination

An Overview of Modern Global Illumination

Figure: Simple scene with computer generated lighting [2]

Examples of Global Illumination

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Figure: Brilliantly lit in-game scene from *Tom Clancy's The Division* [4]

Examples of Global Illumination

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Figure: Realistic scene from Pixar's *Blue Umbrella* [3]

The Power of Light Field Probes

An Overview of Modern Global Illumination

What are **light field probes**?

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- Spheres of emitting light that are suspended in 3D space

Figure: Similar to a nightlight globe [7]

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- Distribution of probes affect scene *radiance*

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The Power of Light Field Probes

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What are **light field probes**?

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- Distribution of probes affect scene *radiance*

Let's see what they look like...

Figure: Similar to a nightlight globe [7]

Examples of Light Field Probes

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Figure: Suspended probes in a scene from Tom Clancy's *The Division* [4]

Examples of Light Field Probes

It's also important to note...

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Figure: Light field probes are approximations of spheres [4]

Why use light field probes?

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Why are they useful?

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    - 3D grid can be iterated over for probe placement

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- Provide robust and flexible scene lighting
  - Can be placed manually in required locations or,
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    - 3D grid can be iterated over for probe placement

Figure: Top view of probes suspended within a 3D grid [2]

Why Use Light Field Probes?

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- Provide realistic lighting by simulating...

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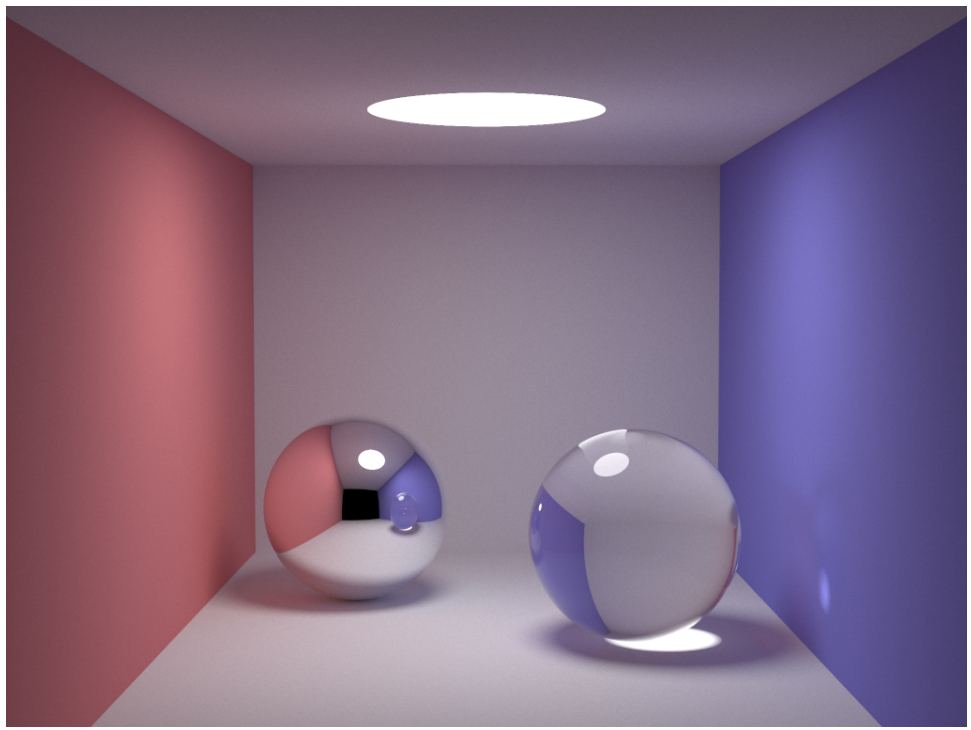

Figure: Scene with 3 properties of realistic light [8]

Why Use Light Field Probes?

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An important contribution of light field probes...

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An important contribution of light field probes...

- Geometry outside of the viewport are viewable from reflections

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Figure: TV and cabinets reflect geometry outside of viewport [2]

How to Create Light Field Probes?

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- To create a single light field probe...

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- To create a single light field probe...
  1. Get an image of surrounding geometry

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- To create a single light field probe...
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     Let's see an example...

Surrounding Geometry Images

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Figure: The famous *Sponza* scene [9]

Surrounding Geometry Images

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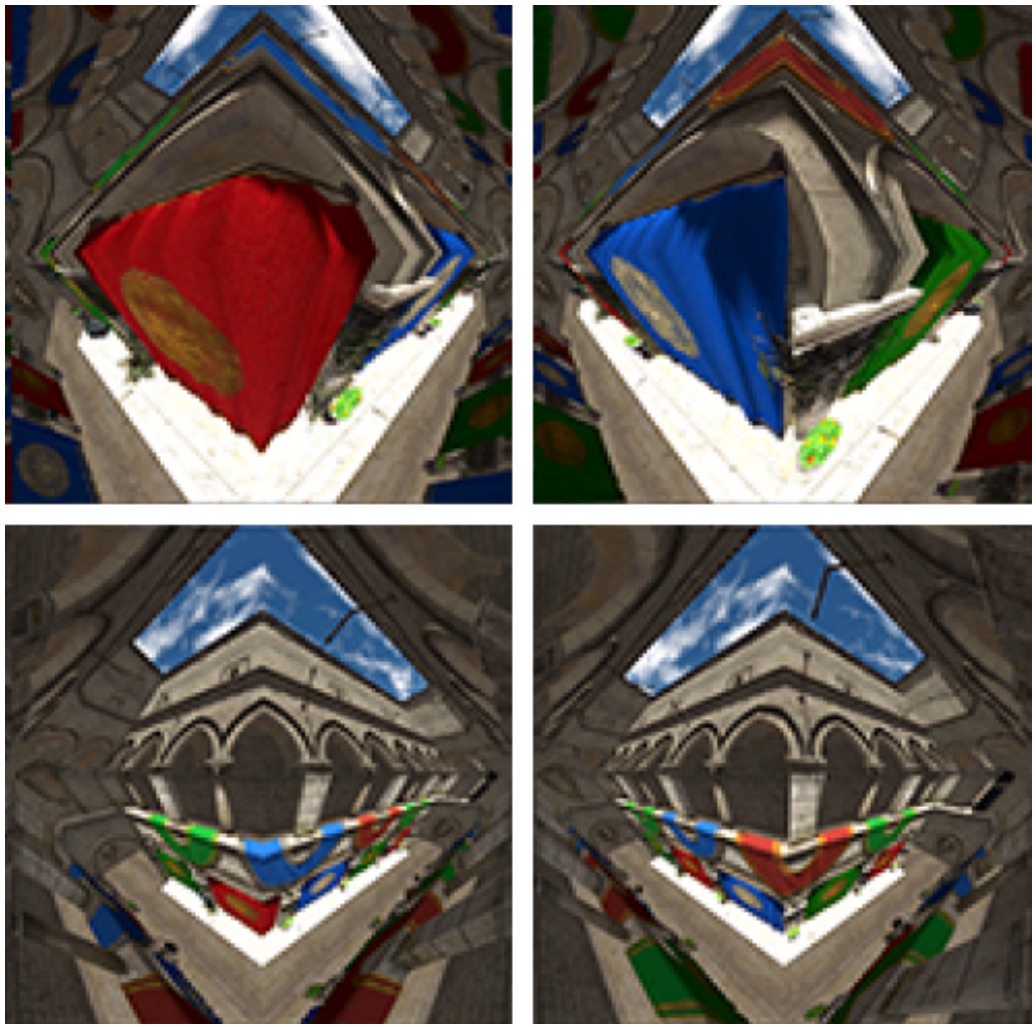

Figure: Enlarged surrounding geometry images [2]

Surrounding Geometry Images

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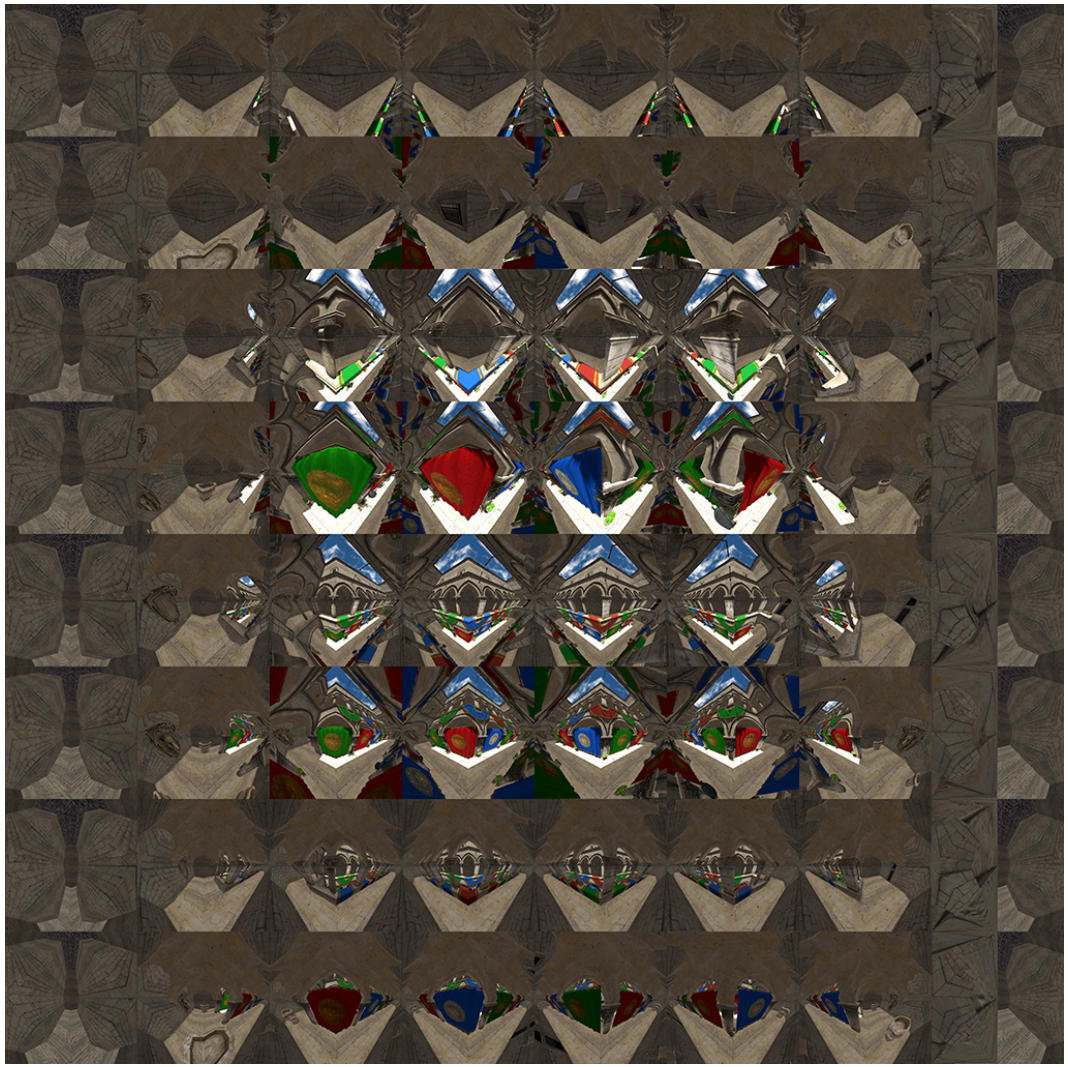

Figure: Collection of surrounding geometry images [2]

How to Create Light Field Probes?

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To create a single light field probe we need...

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   - Surface Material Types

How to Create Light Field Probes?

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To create a single light field probe we need...

1. An image of surrounding geometry

2. Surrounding geometry data
   - Surface Normals & Radial Distances
     - Angle of incident light
   - Surface Material Types
     - Interaction of incident light

How do we use this data...?

Using Surrounding Geometry Images

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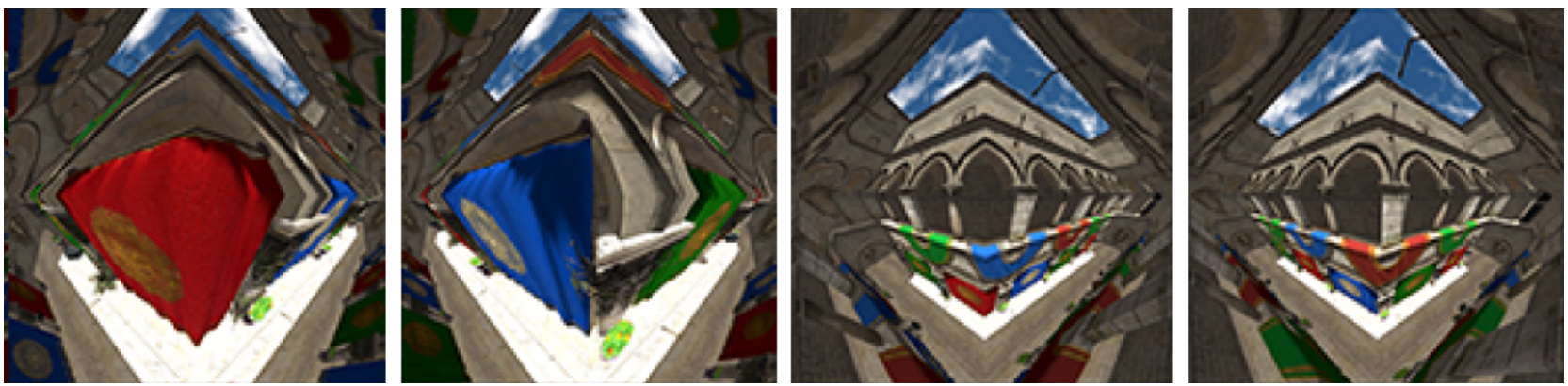

Figure: Enlarged surrounding geometry images from *Sponza* scene [2]

Using Surrounding Geometry Images

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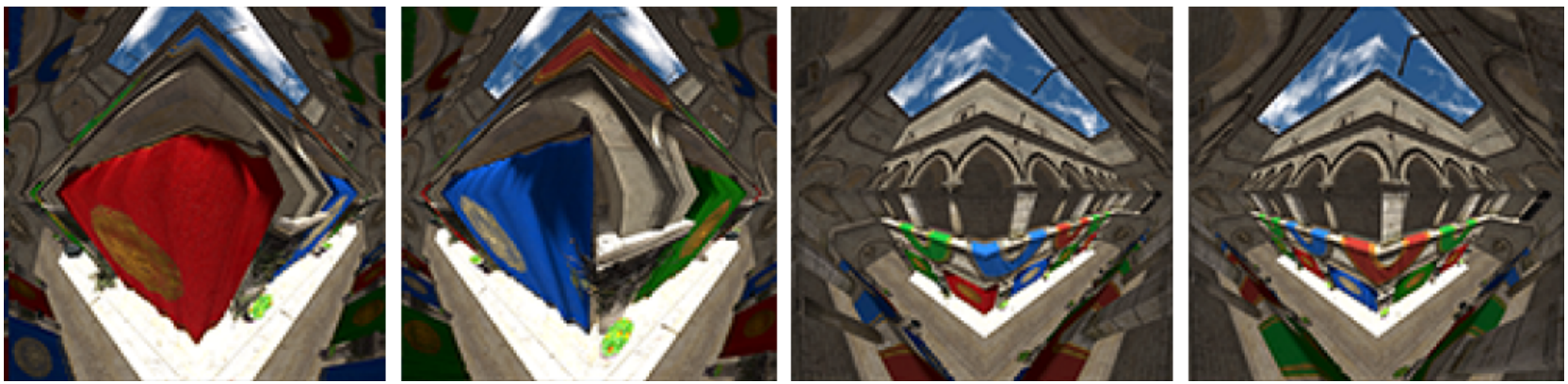
Use images of surrounding geometry to...



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Using Surrounding Geometry Images

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Use images of surrounding geometry to...

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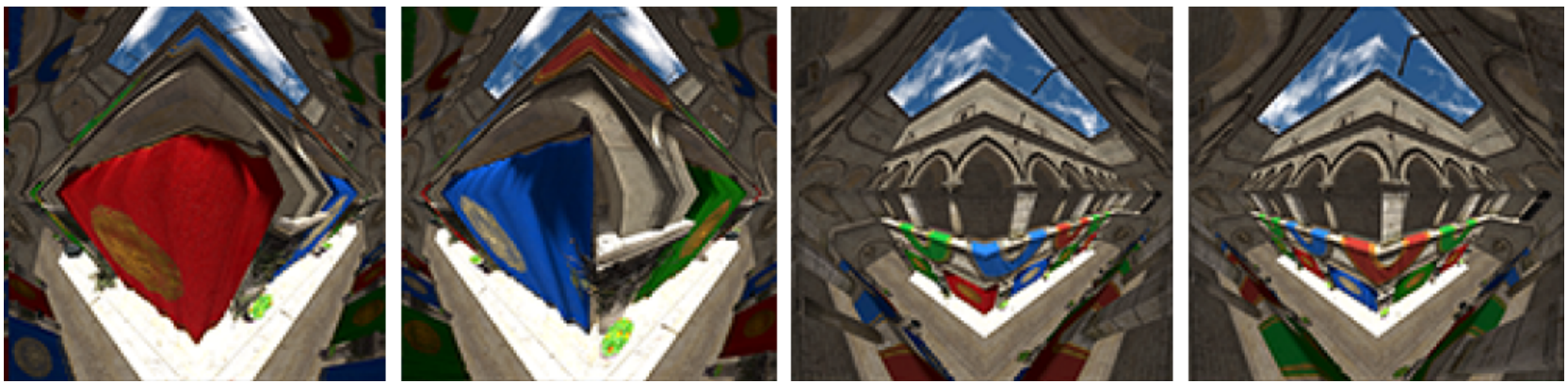

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Using Surrounding Geometry Images

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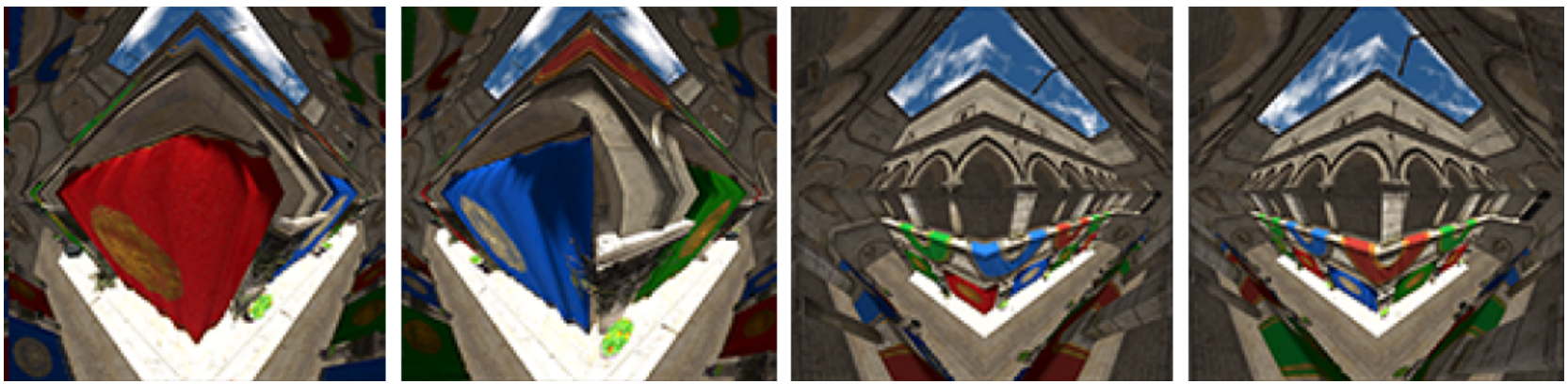
Use images of surrounding geometry to...

- Determine visible geometry
- Apply basic lighting to geometry



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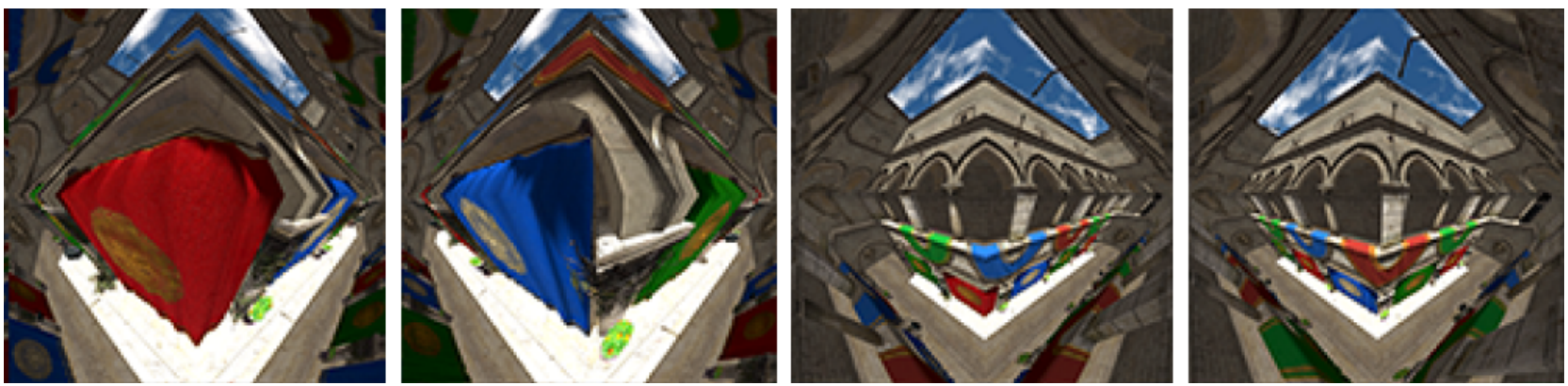

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Ray Tracing

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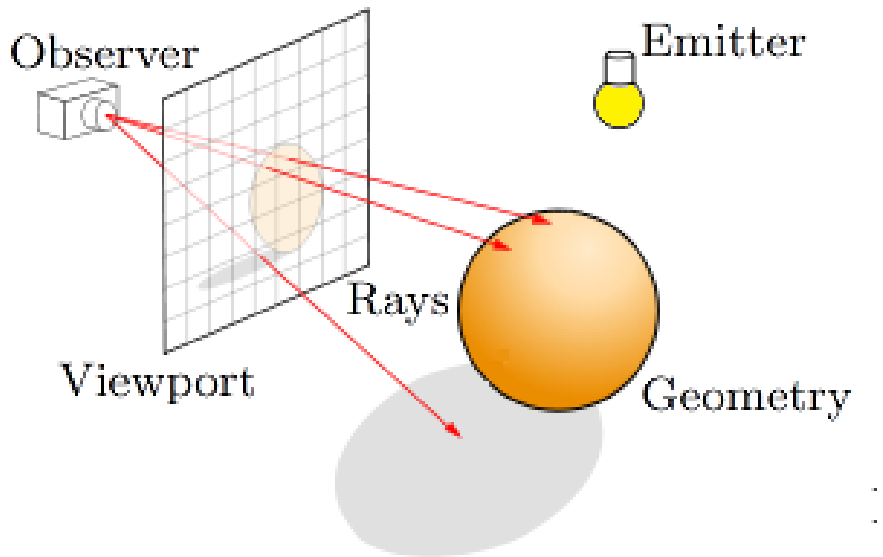

Figure: Visualization of Ray Tracing [5]

Ray Tracing

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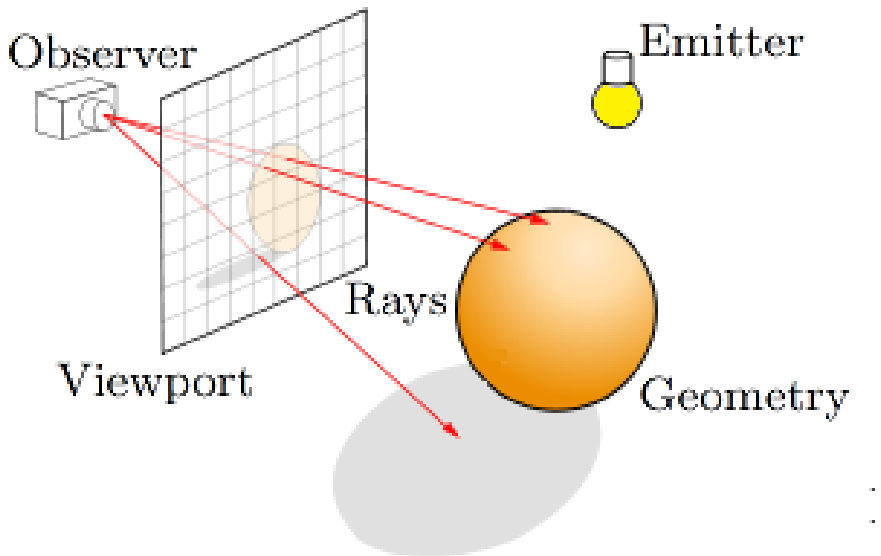
Ray Tracing creates images by...

- Casting rays of light through viewport into the scene
- Intersected geometry and their properties are saved



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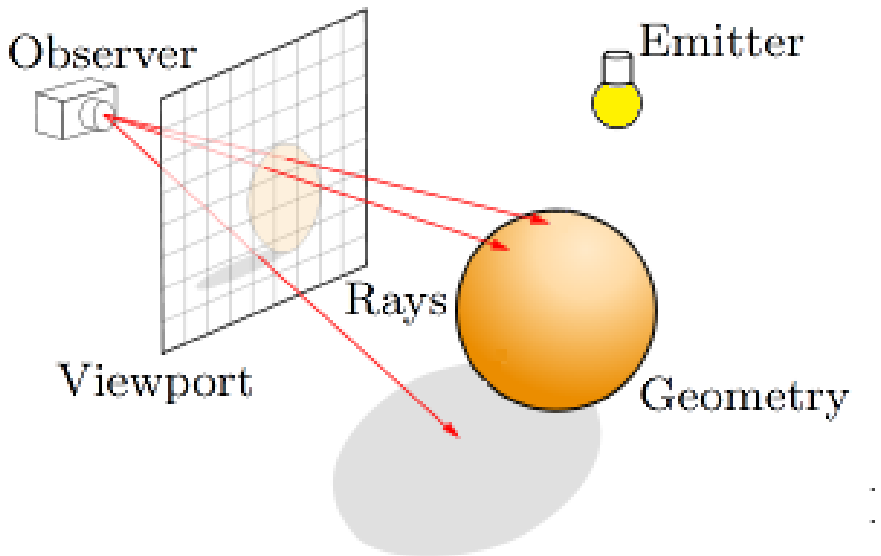
What would a ray tracing probe look like?



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Examples of Light Field Probes

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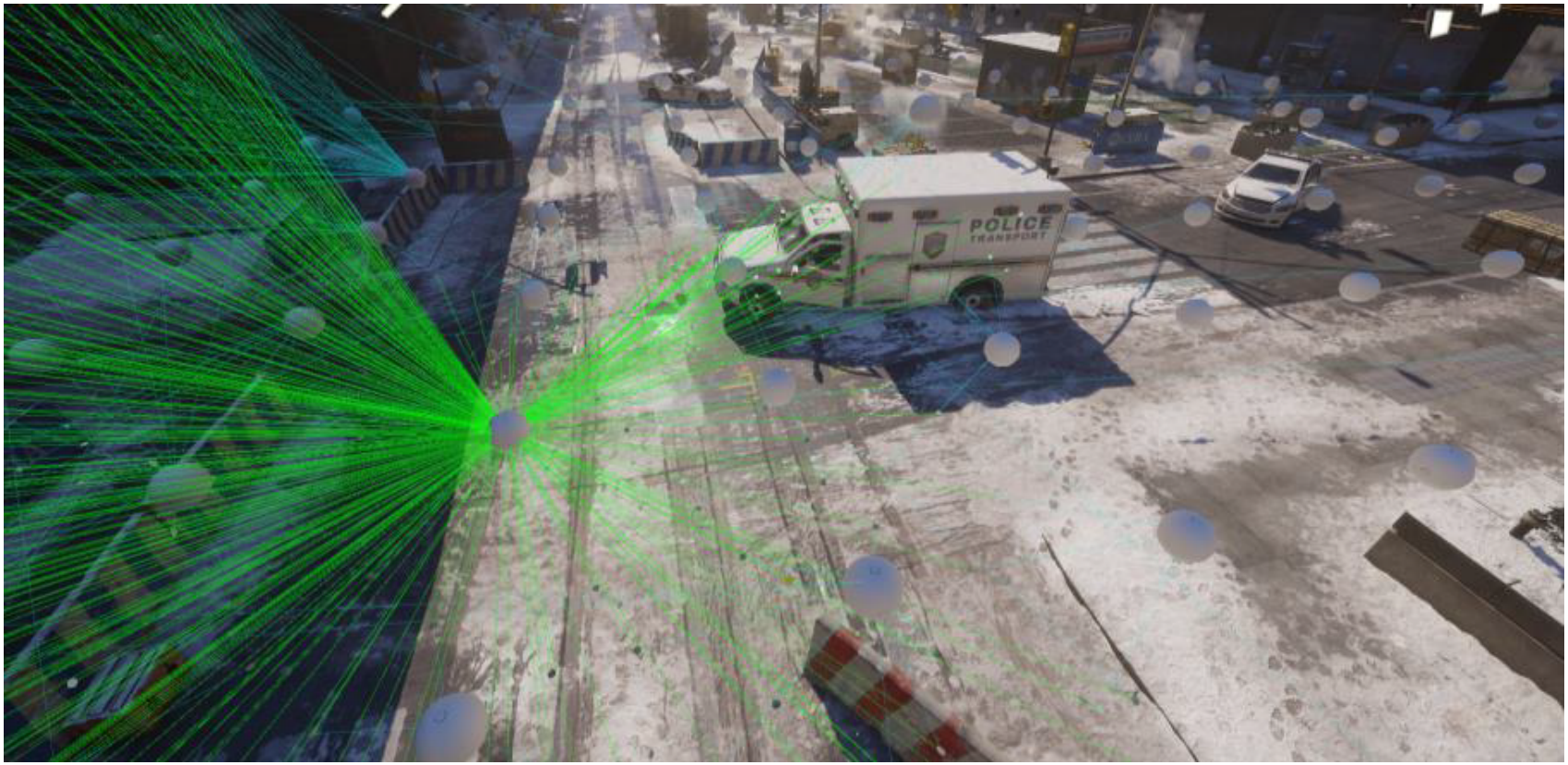

Figure: Green lines visualize probe ray trace of surrounding geometry [4]

Ray Tracing Surrounding Geometry

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Probes are sphere-like... is ray tracing over them possible?

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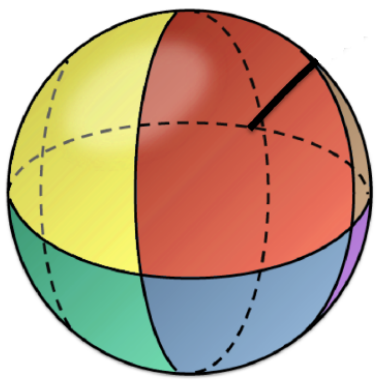

Figure: Sphere to Octahedron to Square [10]

Ray Tracing Surrounding Geometry

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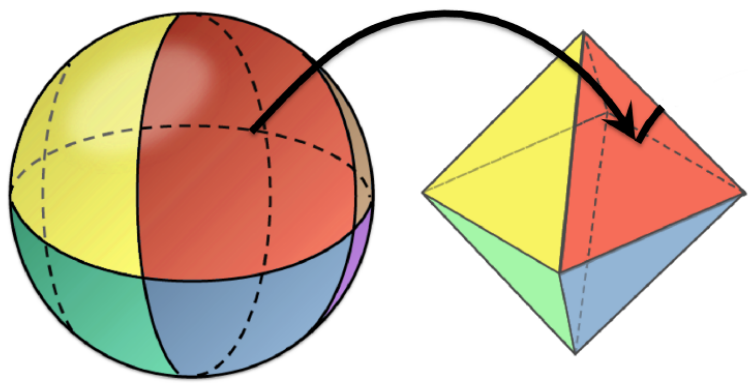
Probes are sphere-like... is ray tracing over them possible?

- Perform a sphere to octahedron mapping



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Ray Tracing Surrounding Geometry

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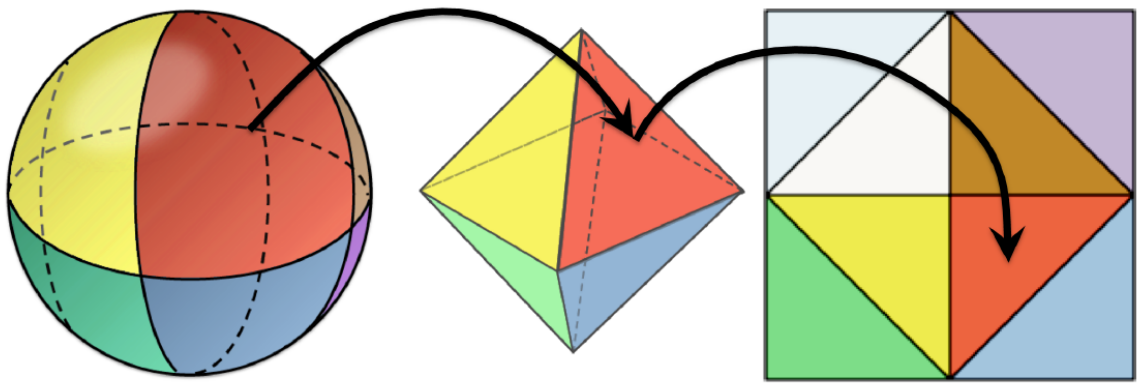
Probes are sphere-like... is ray tracing over them possible?

- Perform a sphere to octahedron mapping
- Project octahedron to 2D plane



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Ray Tracing Surrounding Geometry

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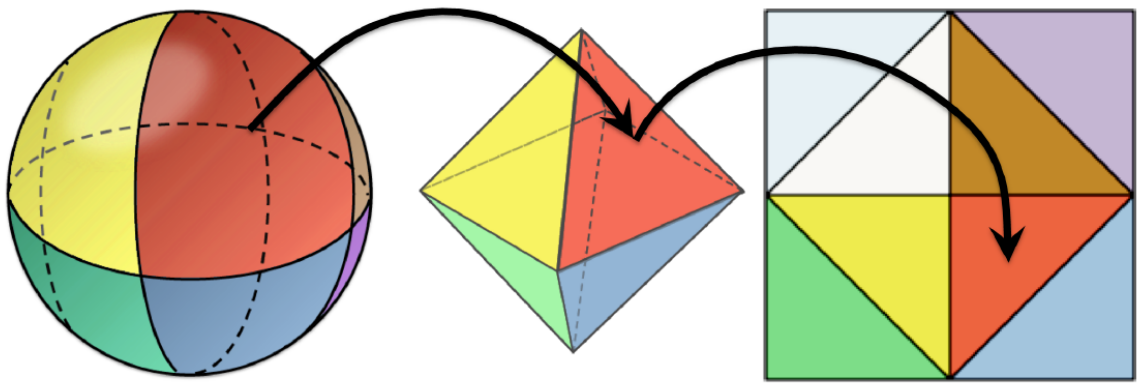
Probes are sphere-like... is ray tracing over them possible?

- Perform a sphere to octahedron mapping
- Project octahedron to 2D plane
- Unfold projection into unit square



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And the result...?

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Figure: Ray Traceable Square Image [2]

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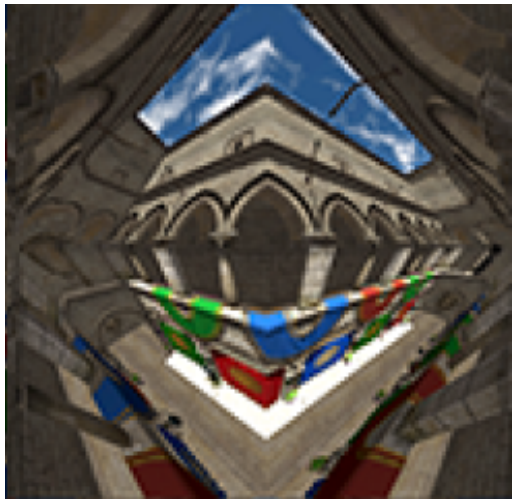

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Ray Tracing Surrounding Geometry

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And the result...?

- A square image that can be ray traced over
- Now we can...
  - Determine visible surrounding geometry
  - Apply basic lighting to surrounding geometry

Figure: Ray Traceable Square Image [2]

Iterating Over Many Probes

We've only considered a single probe...

Iterating Over Many Probes

We've only considered a single probe... what about many probes?

Iterating Over Many Probes

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We've only considered a single probe... what about many probes?

- Start by casting a viewport ray

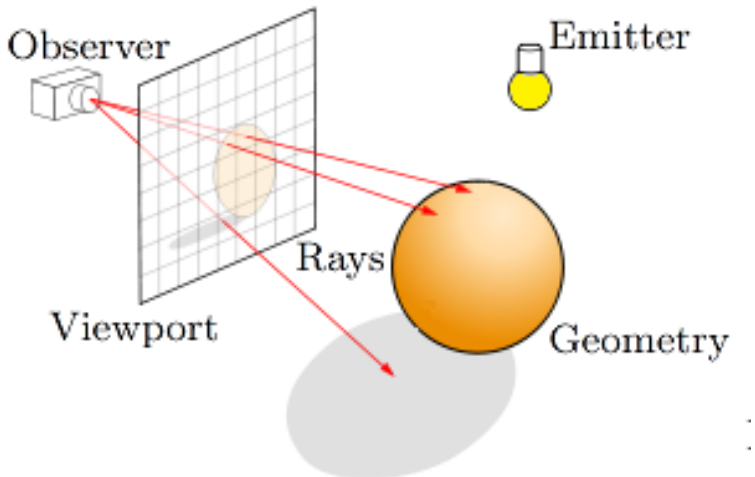

Figure: Cast Viewport Ray

Iterating Over Many Probes

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We've only considered a single probe... what about many probes?

- Start by casting a viewport ray
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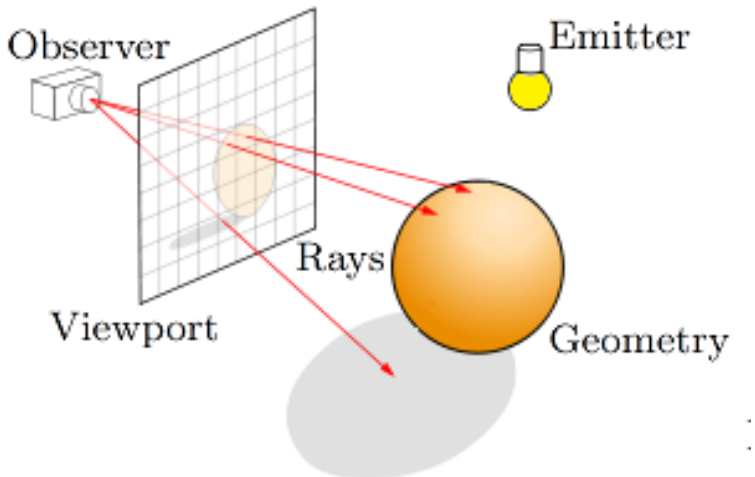

Figure: Cast Viewport Ray

Iterating Over Many Probes

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We've only considered a single probe... what about many probes?

- Start by casting a viewport ray
- Probe closest to viewport ray is selected
- Iterate over probe cage

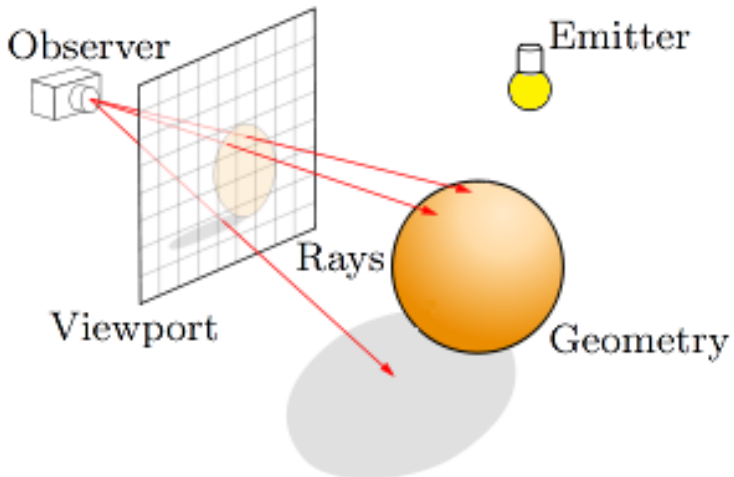

Figure: Cast Viewport Ray

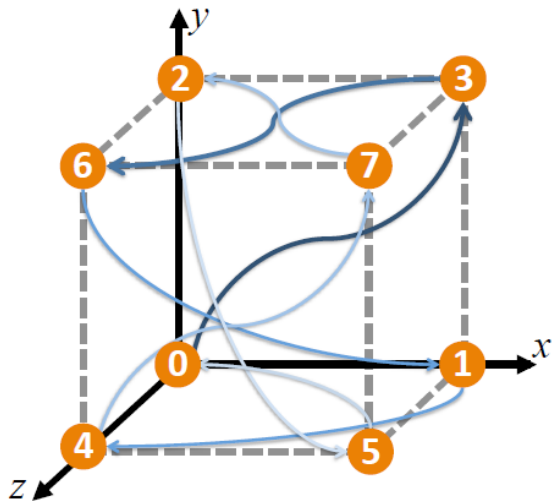

Figure: Probe *Cage* [2]

World-Space Ray Tracing

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Remember this image?

World-Space Ray Tracing

An Overview of Modern Global Illumination

Remember this image?

Figure: TV and cabinets reflect geometry outside of viewport [2]

World-Space Ray Tracing

An Overview of Modern Global Illumination

Remember this image?

- Probes each ray trace

Figure: TV and cabinets reflect geometry outside of viewport [2]

World-Space Ray Tracing

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World-Space Ray Tracing

An Overview of Modern Global Illumination

Remember this image?

- Probes each ray trace
- Probes intersect geometry outside of viewport
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Figure: TV and cabinets reflect geometry outside of viewport [2]

World-Space Ray Tracing

An Overview of Modern Global Illumination

Remember this image?

- Probes each ray trace
- Probes intersect geometry outside of viewport
- Geometry traced outside of viewport stored
- Results in **World-Space Ray Tracing**

Figure: TV and cabinets reflect geometry outside of viewport [2]

Achieving Realistic Lighting

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To simulate effects of light like...

Achieving Realistic Lighting

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To simulate effects of light like...

- Soft Shadows

Achieving Realistic Lighting

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To simulate effects of light like...

- Soft Shadows, Reflections

Achieving Realistic Lighting

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To simulate effects of light like...

- Soft Shadows, Reflections and Refractions

Achieving Realistic Lighting

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We need to describe...

Achieving Realistic Lighting

An Overview of Modern Global Illumination

To simulate effects of light like...

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We need to describe...

- Light models for each surface type

Achieving Realistic Lighting

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To simulate effects of light like...

- Soft Shadows, Reflections and Refractions

We need to describe...

- Light models for each surface type
  - Determine distribution of reflected light

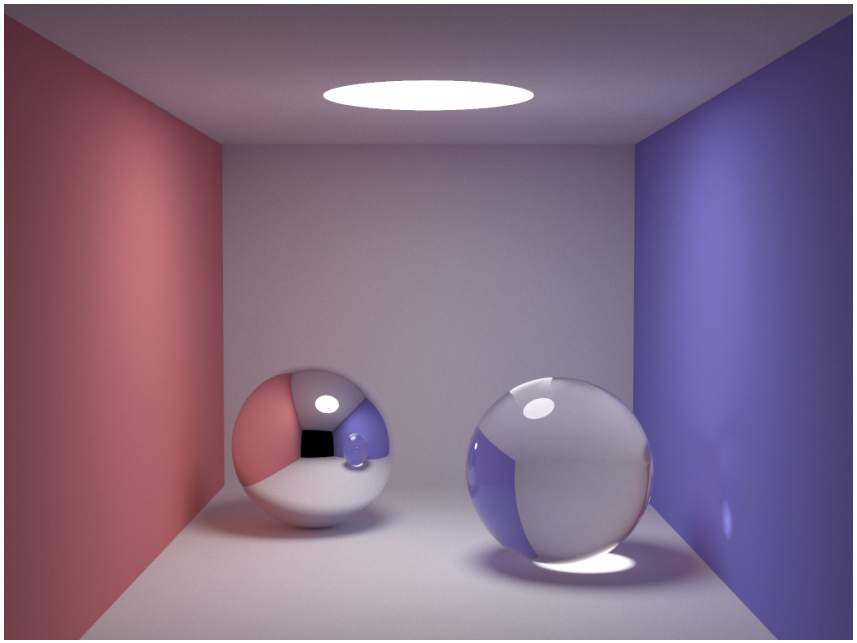

Figure: Scene with 3 properties of realistic light

Light Modeling for Surface Types

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Modeling reflected light for surface types...?

Light Modeling for Surface Types

An Overview of Modern Global Illumination

Modeling reflected light for surface types...?

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Light Modeling for Surface Types

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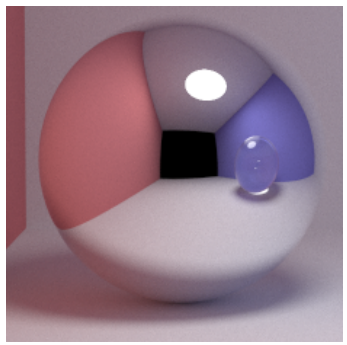

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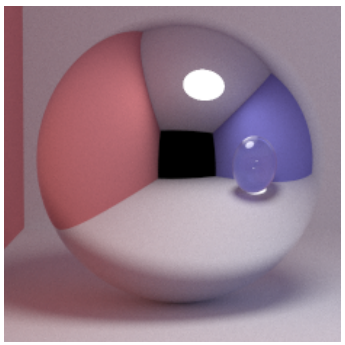

Light Modeling for Surface Types

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Modeling reflected light for surface types...?

- Surfaces like...
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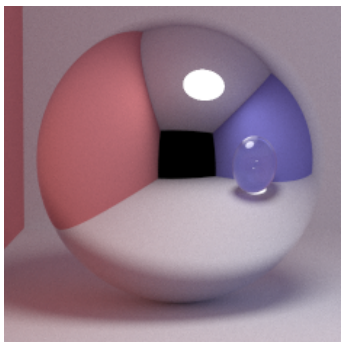
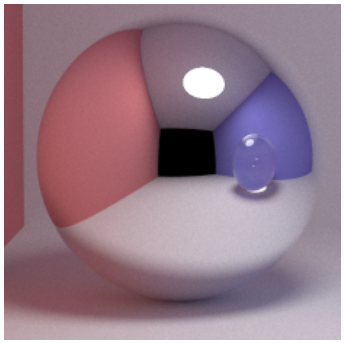


Light Modeling for Surface Types

An Overview of Modern Global Illumination

Modeling reflected light for surface types...?

- Surfaces like...
  - Glass, Wood, Cloth, Water, Asphalt and many more...



A Look at Surface Types

An Overview of Modern Global Illumination

Close up of...

A Look at Surface Types

An Overview of Modern Global Illumination

Close up of... **diffusely** reflective surface

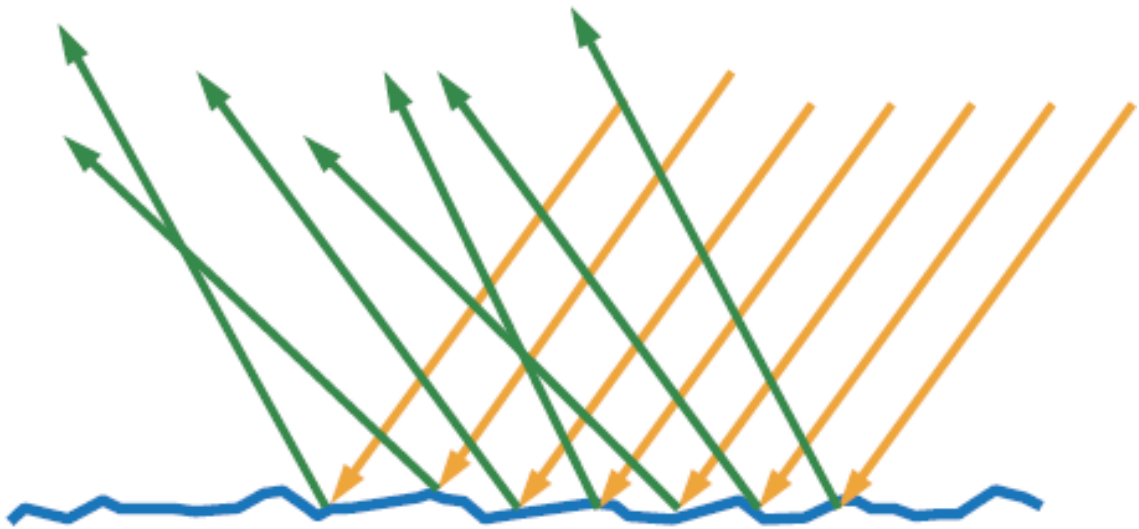


Figure: Diffuse reflections due to microgeometry [11]

A Look at Surface Types

An Overview of Modern Global Illumination

Close up of... **diffusely** reflective surface

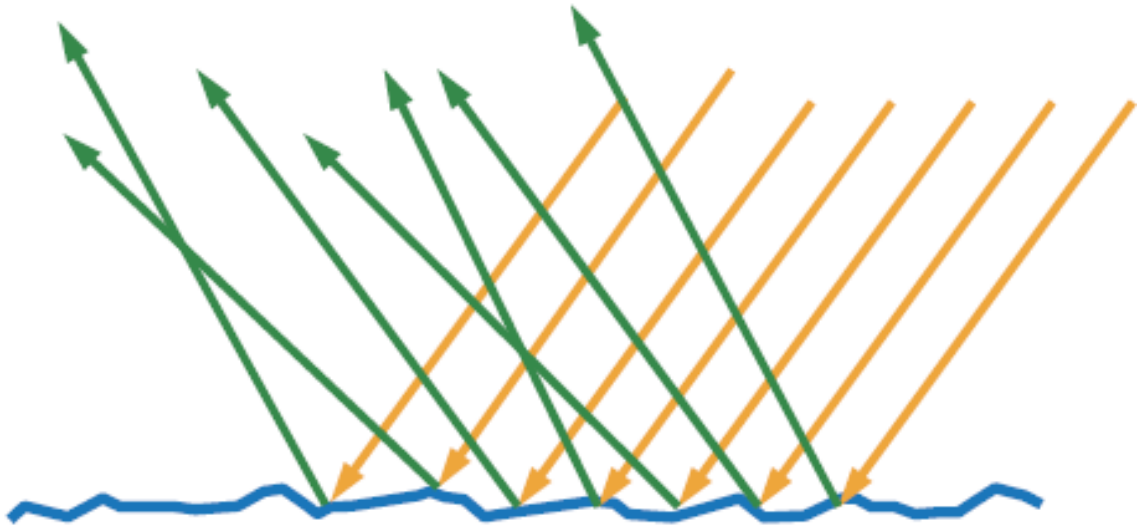


Figure: Diffuse reflections due to microgeometry [11]

A Look at Surface Types

An Overview of Modern Global Illumination

Close up of... **diffusely** reflective surface

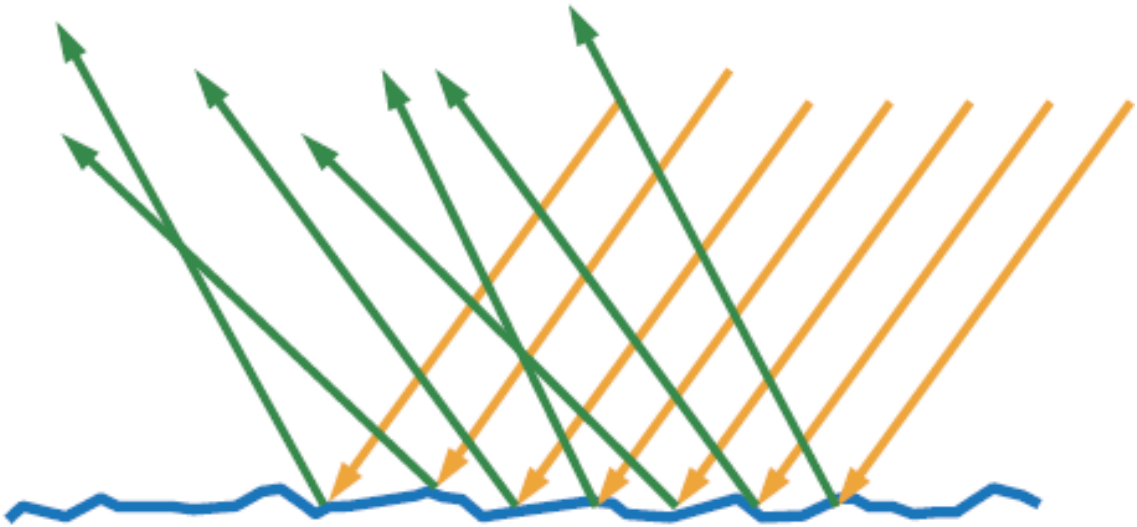


Figure: Diffuse reflections due to microgeometry [11]

Models of Light Distribution

An Overview of Modern Global Illumination

Close up of...

Models of Light Distribution

An Overview of Modern Global Illumination

Close up of... **specularly** reflective surface

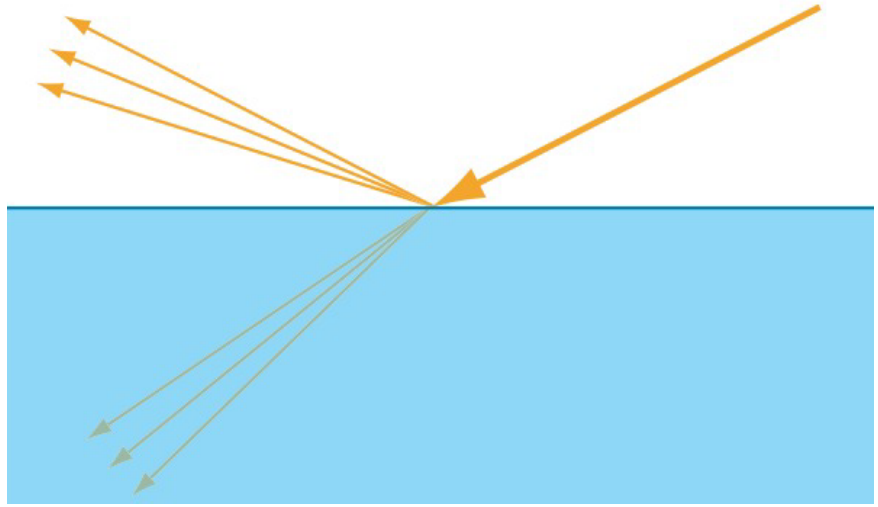
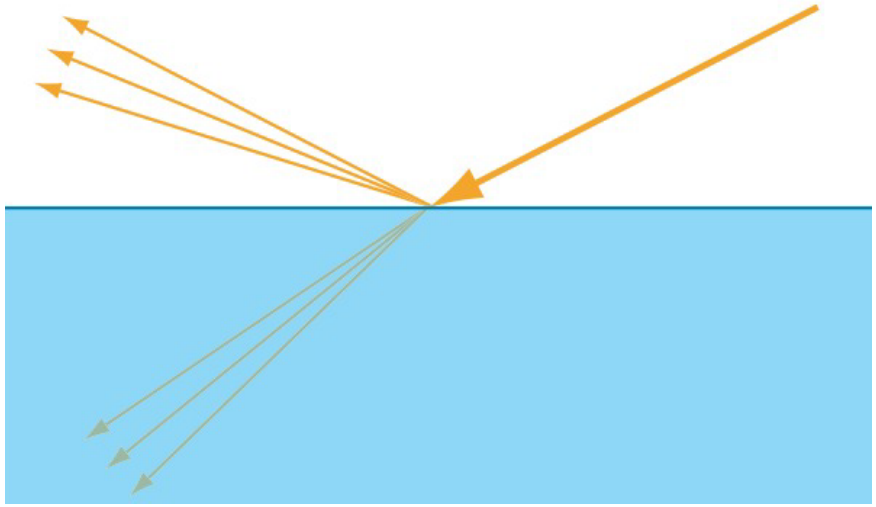


Figure: Specular reflection and clean refraction [11]

Models of Light Distribution

An Overview of Modern Global Illumination

Close up of... **specularly** reflective surface



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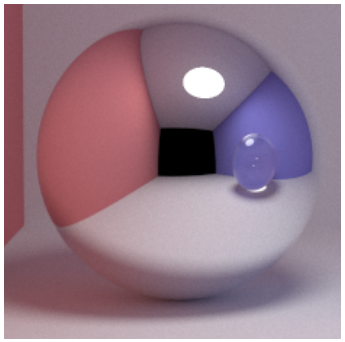
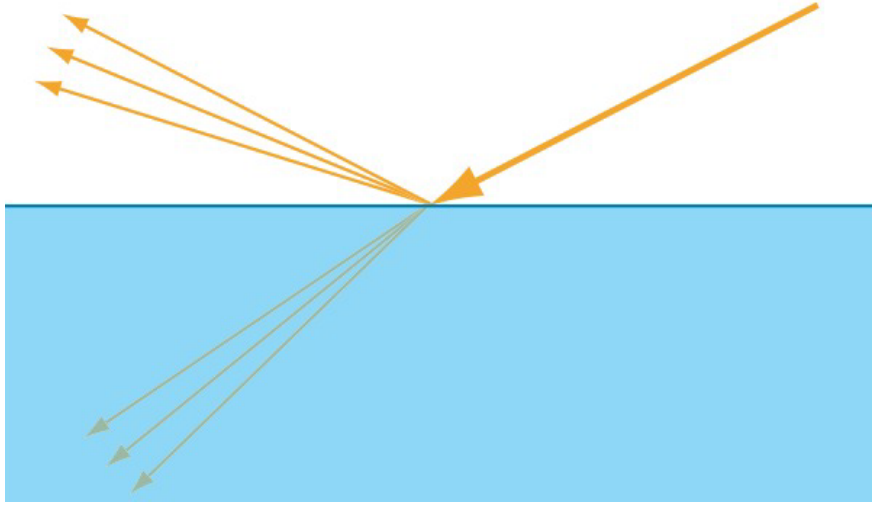
Models of Light Distribution

An Overview of Modern Global Illumination

Close up of... **specularly** reflective surface





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Models of Light Distribution

An Overview of Modern Global Illumination

Close up of... another **specularly** reflective surface

Models of Light Distribution

An Overview of Modern Global Illumination

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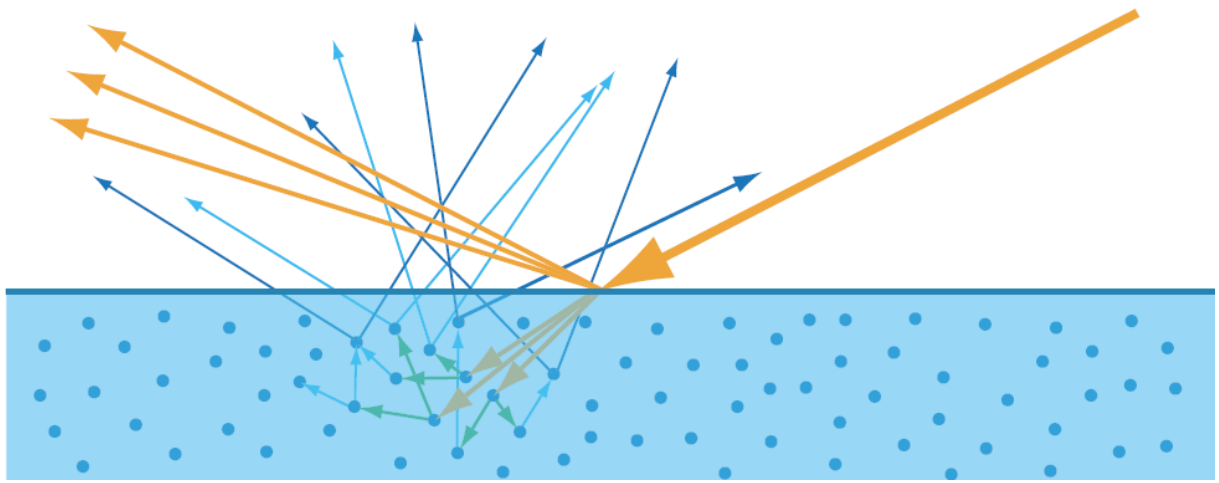


Figure: Specular reflection with scattered refraction [11]

Models of Light Distribution

An Overview of Modern Global Illumination

Close up of... another **specularly** reflective surface

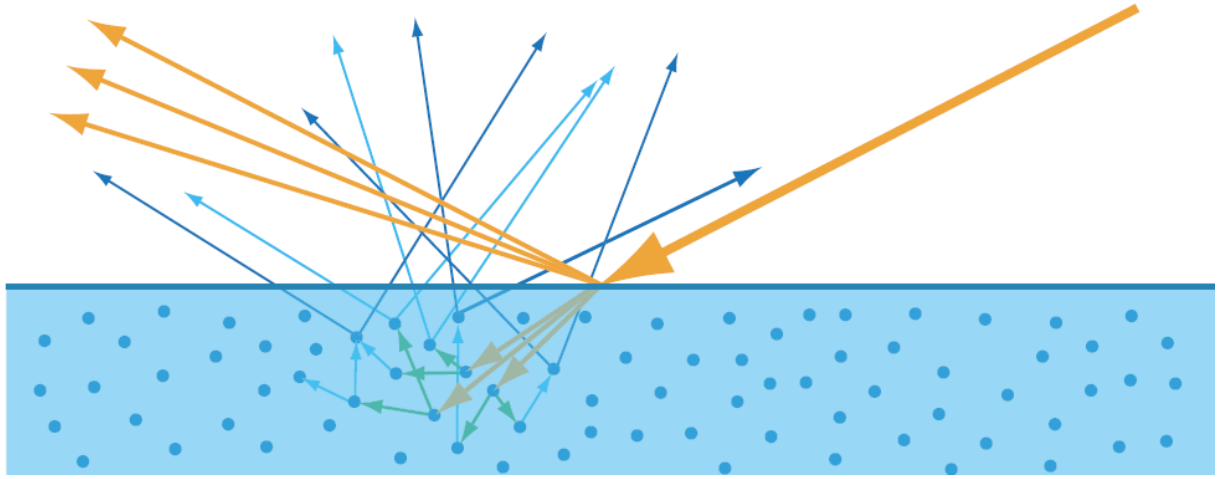
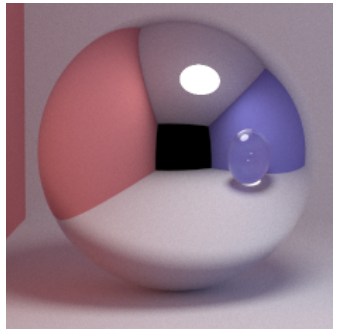


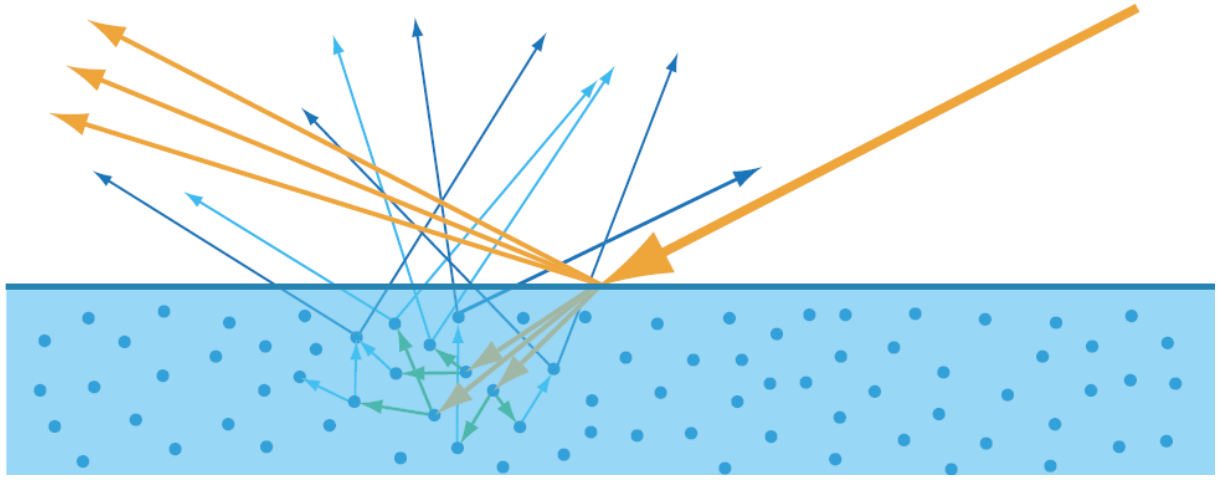
Figure: Specular reflection with scattered refraction [11]

Models of Light Distribution

An Overview of Modern Global Illumination

Close up of... another **specularly** reflective surface





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Modeling Light Distribution

An Overview of Modern Global Illumination

How do we model light distribution from surfaces?

Modeling Light Distribution

An Overview of Modern Global Illumination

How do we model light distribution from surfaces?

- Bidirectional Reflectance Distribution Function (BRDF)

Modeling Light Distribution

How do we model light distribution from surfaces?

- Bidirectional Reflectance Distribution Function (BRDF)
  - Defines how surface types distribute reflected light

Modeling Light Distribution

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  - Can be mathematically defined by...

Modeling Light Distribution

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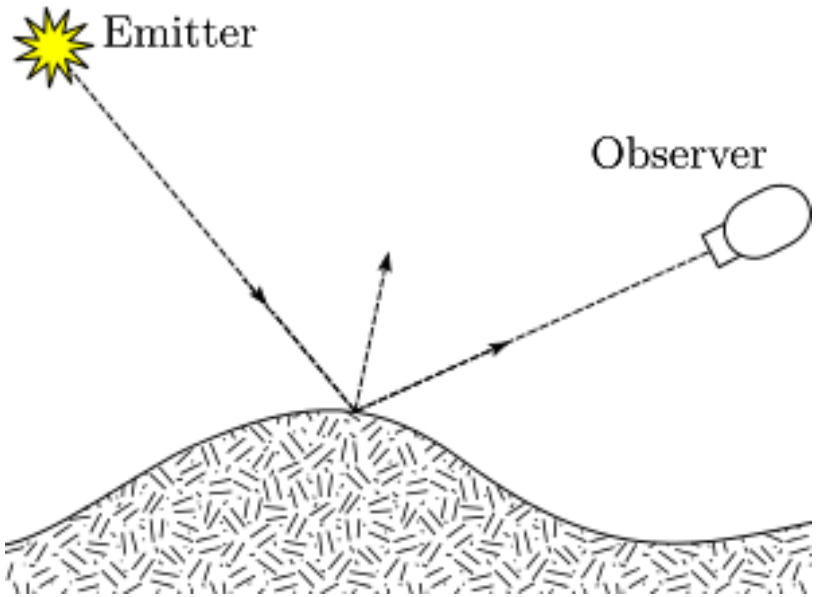

Figure: BDRF Visualization

Modeling Light Distribution

An Overview of Modern Global Illumination

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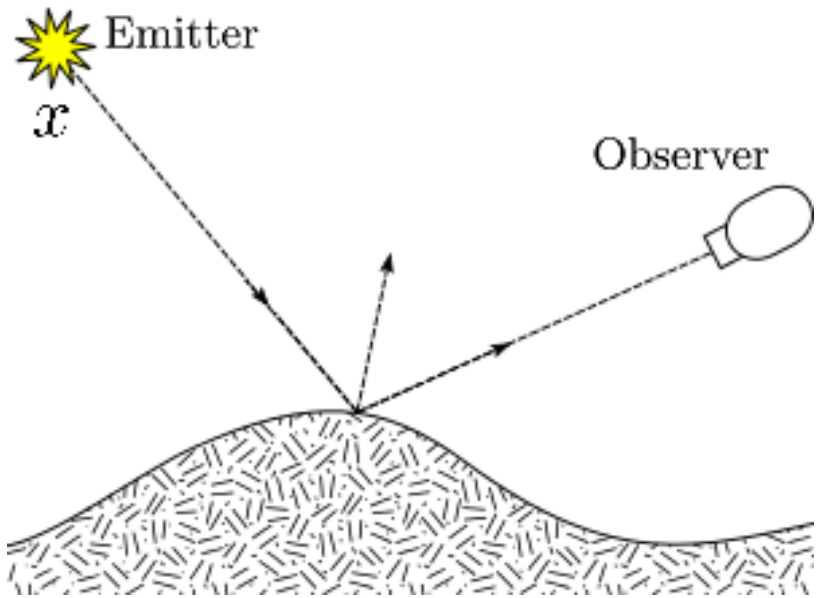
$$\mathrm{L}\left(x, \qquad \right)$$



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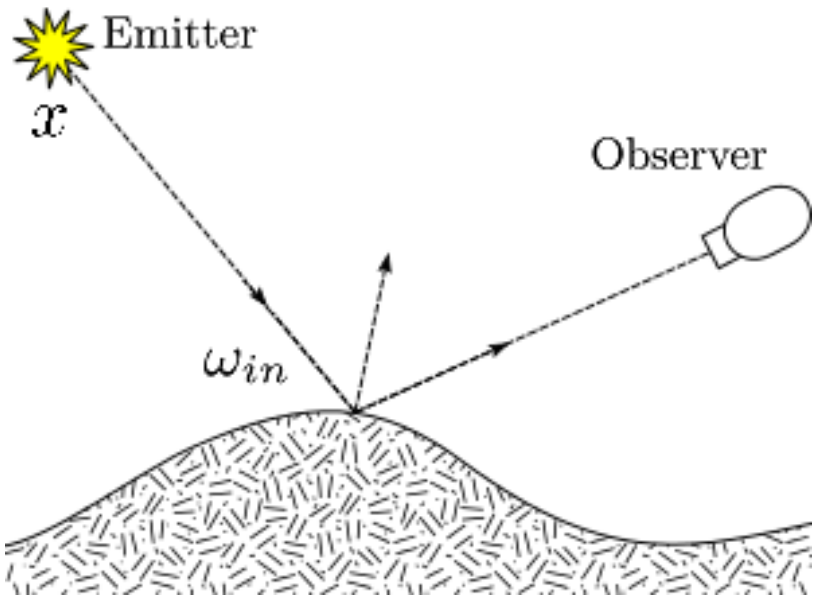

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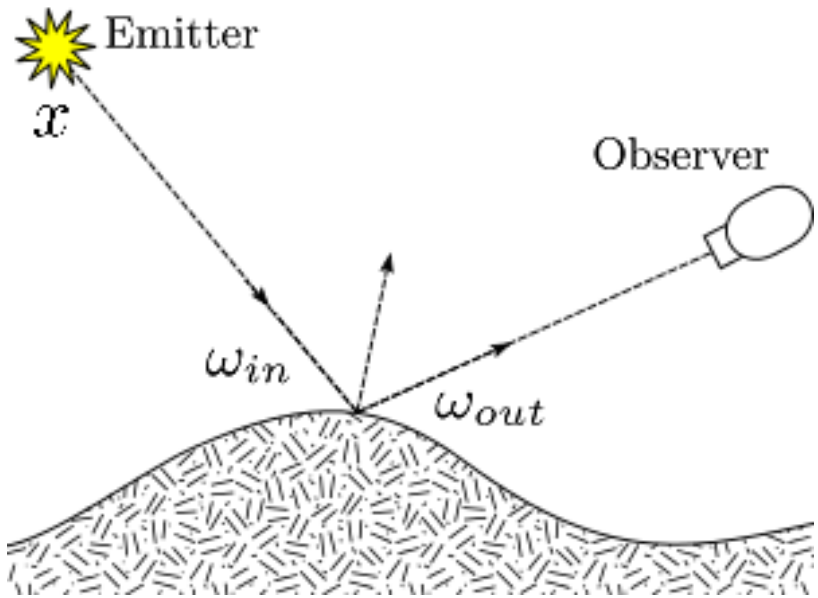

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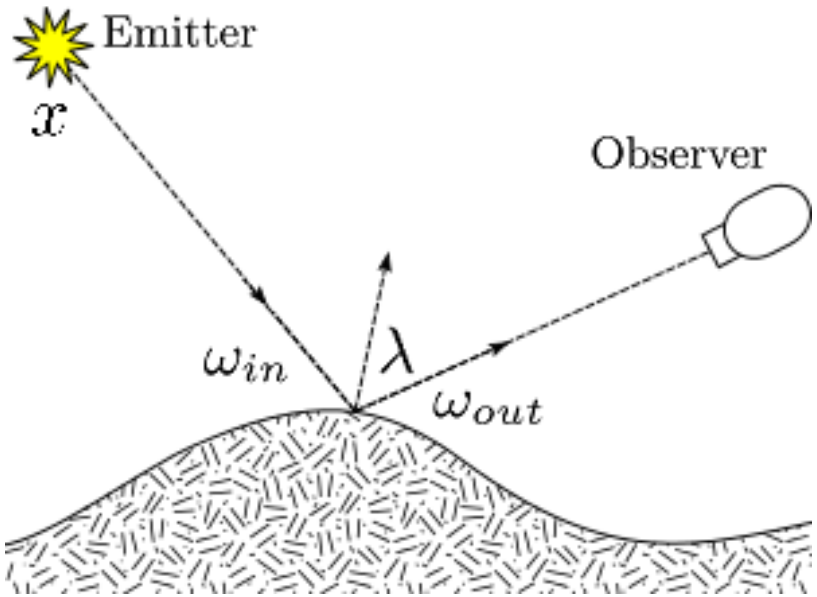

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Modeling Light Distribution

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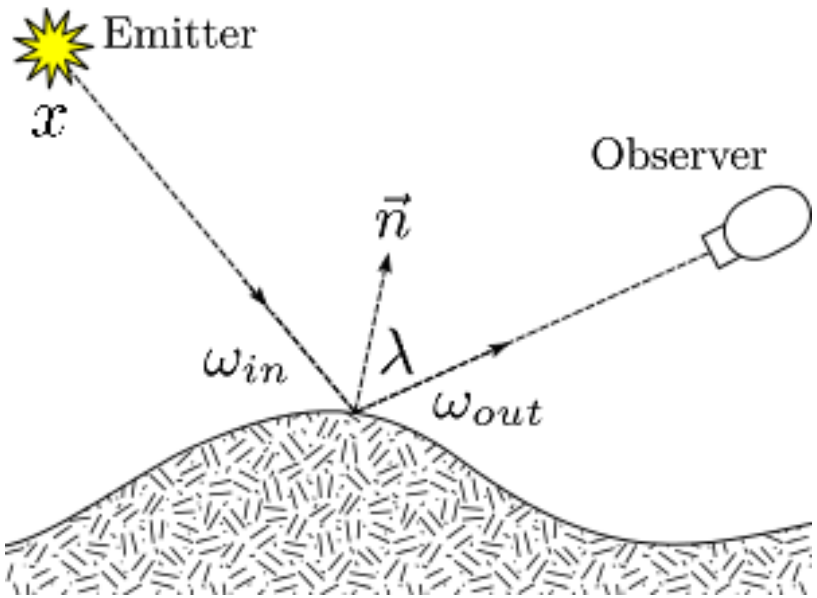


Figure: BDRF Visualization

Pulling It All Together

An Overview of Modern Global Illumination

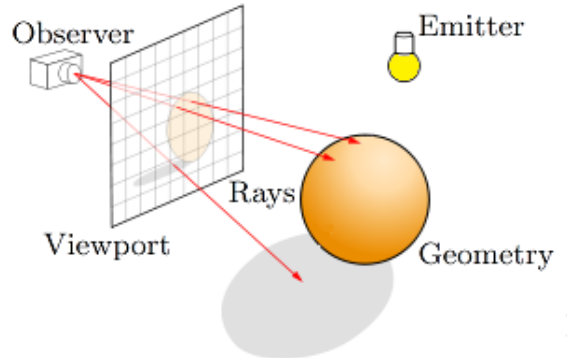
Tools for global illumination...

Pulling It All Together

An Overview of Modern Global Illumination

Tools for global illumination...

- Light field probe world-space ray tracing

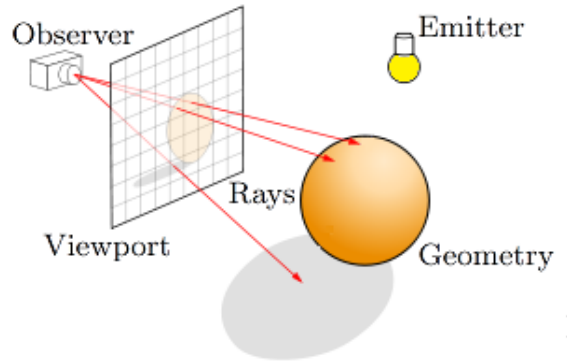


Pulling It All Together

An Overview of Modern Global Illumination

Tools for global illumination...

- Light field probe world-space ray tracing
  - Visibility and lighting of surrounding geometry



Pulling It All Together

An Overview of Modern Global Illumination

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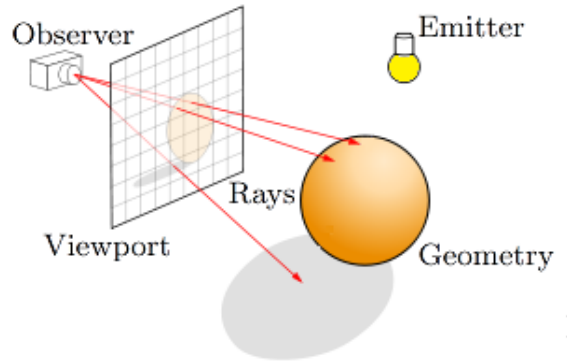

Pulling It All Together

An Overview of Modern Global Illumination

Tools for global illumination...

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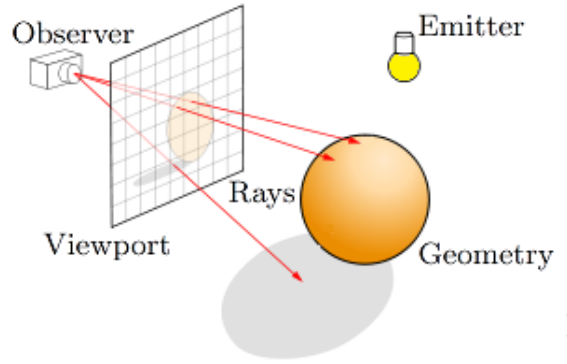
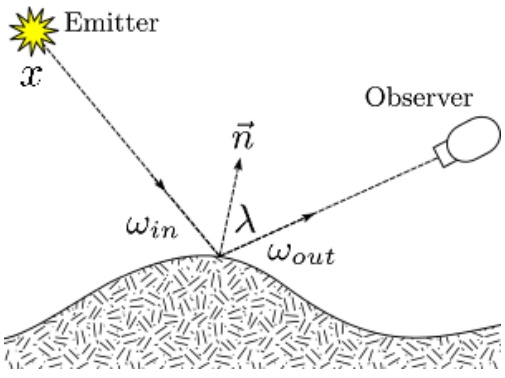
  - Visibility and lighting of surrounding geometry
- Reflected light (BRDFs)



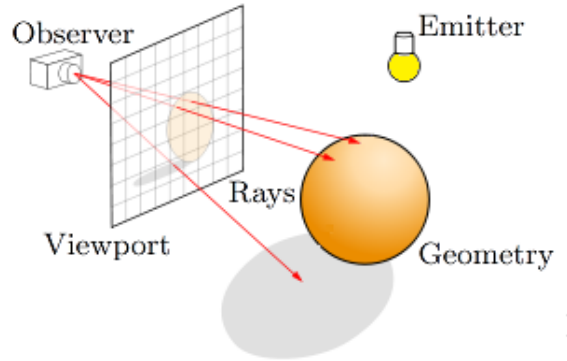


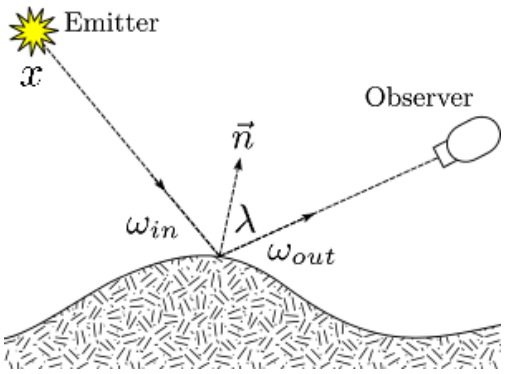
Pulling It All Together

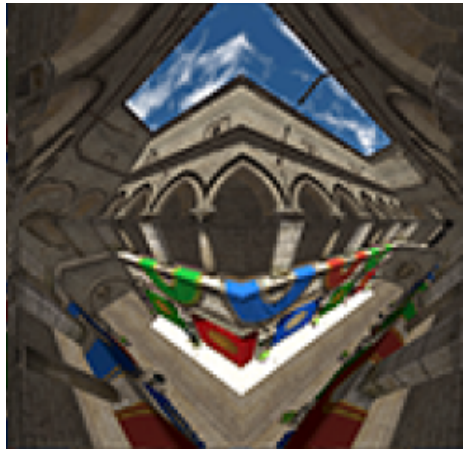
An Overview of Modern Global Illumination

Tools for global illumination...

- Light field probe world-space ray tracing
  - Visibility and lighting of surrounding geometry
- Reflected light (BRDFs)
  - Realistic lighting with surface types







The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together...

The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data

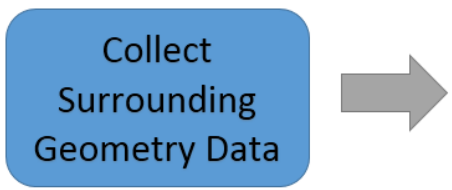


Figure: Deferred renderer pipeline

The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data
   - Spherical Images

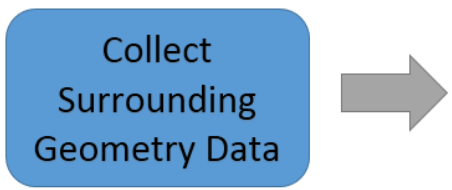


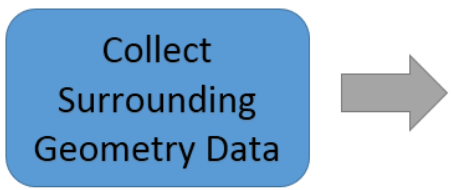
Figure: Deferred renderer pipeline

The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data
   - Spherical Images
   - Surface Material Types



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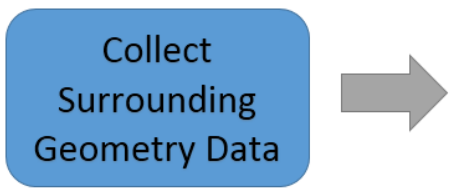
The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data
   - Spherical Images
   - Surface Material Types
   - Surface Normals



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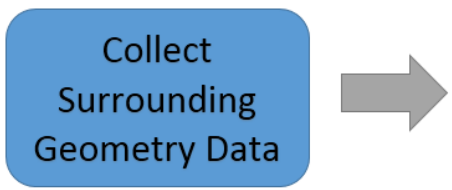
The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data
   - Spherical Images
   - Surface Material Types
   - Surface Normals
   - Radial Distances



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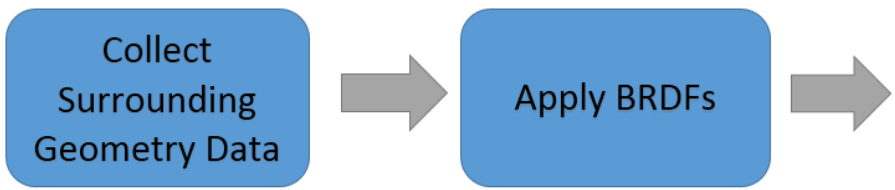
The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data
   - Spherical Images
   - Surface Material Types
   - Surface Normals
   - Radial Distances
2. Apply light reflectance distribution models



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The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data
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   - Surface Material Types
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   - Radial Distances
2. Apply light reflectance distribution models
   - BRDFs for each surface type

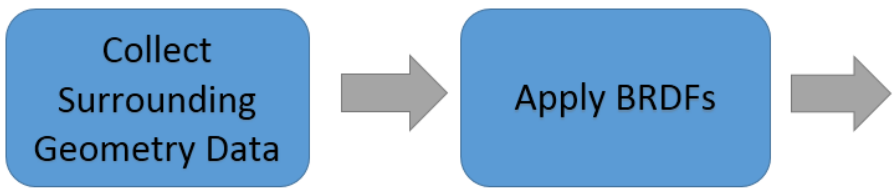

Figure: Deferred renderer pipeline

The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data
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   - Surface Normals
   - Radial Distances
2. Apply light reflectance distribution models
   - BRDFs for each surface type
3. Render image

Figure: Deferred renderer pipeline

The Rendering Pipeline

An Overview of Modern Global Illumination

Use the tools together... for a *deferred renderer*

1. Collect surrounding geometry data
   - Spherical Images
   - Surface Material Types
   - Surface Normals
   - Radial Distances
2. Apply light reflectance distribution models
   - BRDFs for each surface type
3. Render image
   - Reveal image to observer

Figure: Deferred renderer pipeline

The Final Product

An Overview of Modern Global Illumination

Once the rendering pipeline finishes...

Figure: Brilliantly lit in-game scene from *Tom Clancy's The Division*

Conclusion

An Overview of Modern Global Illumination

Contributions to global illumination methods...

Conclusion

An Overview of Modern Global Illumination

Contributions to global illumination methods...

- Flexible and robust light field probes

Conclusion

An Overview of Modern Global Illumination

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An Overview of Modern Global Illumination

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  - Ray traceable surrounding geometry
- World-space ray tracing

Conclusion

An Overview of Modern Global Illumination

Contributions to global illumination methods...

- Flexible and robust light field probes
  - Manually or automatically placeable within a scene
  - Ray traceable surrounding geometry
- World-space ray tracing
  - Geometry outside of the viewport visible from reflections

Wrap Up

An Overview of Modern Global Illumination

Thanks for listening!

Wrap up

An Overview of Modern Global Illumination

Thanks for Listening!

Questions

An Overview of Modern Global Illumination

Any Questions?

Sources

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