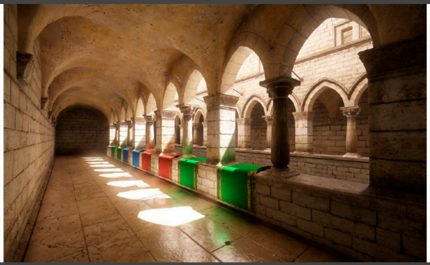
Real-Time High Quality Rendering

GAMES202, Lingqi Yan, UC Santa Barbara

Lecture 9:
Real-Time Global Illumination
(screen space cont.)

Announcements

- Happy Labor Day!
- Milestone: 2/3 contents covered after today's lecture!
- GAMES101 homework resubmission
  - Still recruiting graders!
  - I'm considering TAs instead of graders now
- GAMES202 homework late submission
  - Will start after HW2 is due
- I may suddenly cancel any lecture before May 20

Errata

- In RSM (Lecture 7)
  - Both my derivation and the equation from paper are CORRECT

$$L_o(\mathrm{p}, \omega_o) = \int_{\Omega_{\mathrm{patch}}} L_i(\mathrm{p}, \omega_i)\, V(\mathrm{p}, \omega_i) f_r(\mathrm{p}, \omega_i, \omega_o)\, \cos\theta_i\, \mathrm{d}\omega_i$$

$$= \int_{A_{\mathrm{patch}}} L_i(\mathrm{q} \to \mathrm{p})\, V(\mathrm{p}, \omega_i) f_r(\mathrm{p}, \mathrm{q} \to \mathrm{p}, \omega_o)\, \frac{\cos\theta_p \cos\theta_q}{\|q - p\|^2}\, \mathrm{d}A$$

$$E_p(x,n) = \Phi_p \frac{\max\{0, \langle n_p | x - x_p \rangle\} \max\{0, \langle n | x_p - x \rangle\}}{\|x - x_p\|^4}. \qquad (1)$$

Last Lecture

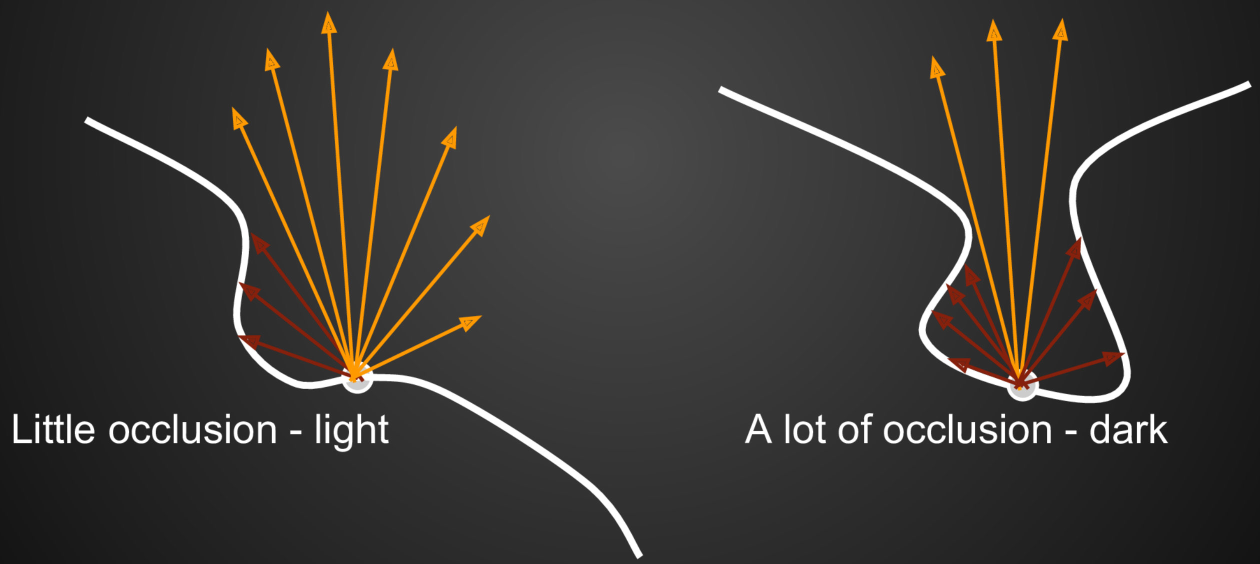
- Real-Time Global Illumination (3D space)
  - Light Propagation Volumes (LPV)
  - Voxel Global Illumination (VXGI)
- Real-Time Global Illumination (screen space)
  - Screen Space Ambient Occlusion (SSAO)
  - Screen Space Directional Occlusion (SSDO)
  - Screen Space Reflection (SSR)

Today

- Real-Time Global Illumination (screen space cont.)
  - Screen Space Directional Occlusion (SSDO)
  - Screen Space Reflection (SSR)
- Real-Time Physically-Based Materials

Recap: Screen Space Ambient Occlusion (SSAO)

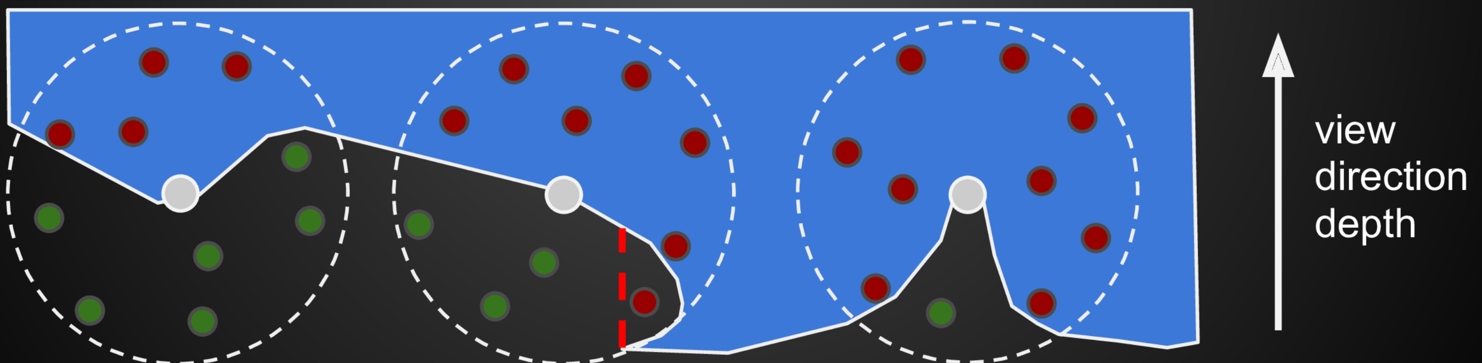
Ambient occlusion



SSAO:
Ambient occlusion using the z-buffer

Use the readily available depth buffer as an approximation of the scene geometry.

Take samples in a sphere around each pixel and test against buffer.

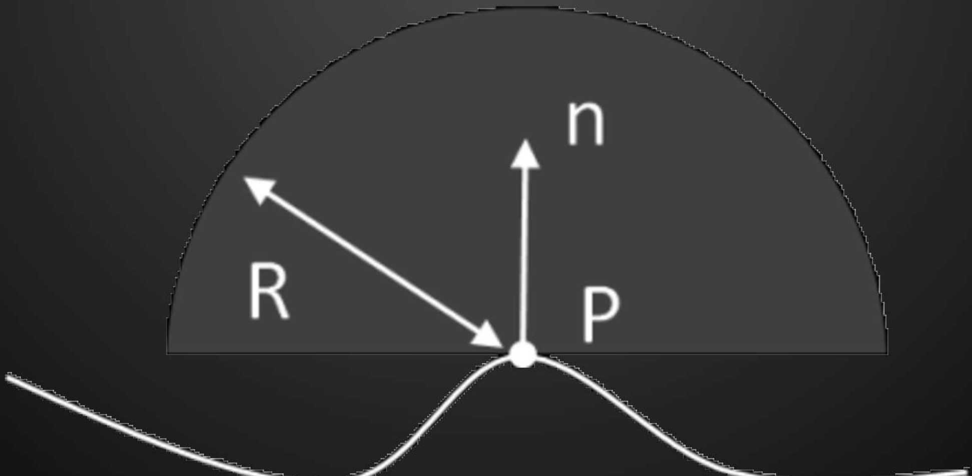


Horizon based ambient occlusion: HBAO

Also done in screen space.

Approximates ray-tracing the depth buffer.

Requires that the normal is known, and only samples in a hemisphere.



Screen Space Directional Occlusion (SSDO)

Screen Space Directional Occlusion

- What is SSDO?
  - An improvement over SSAO

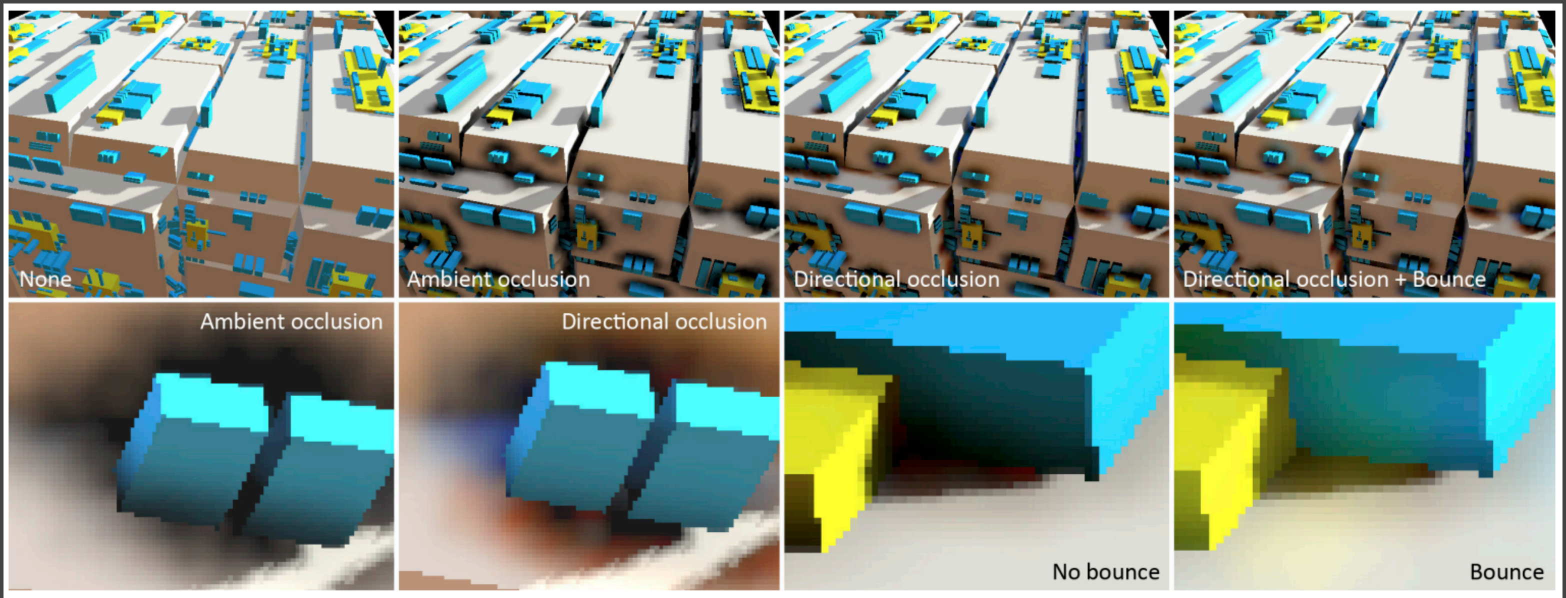
    考虑更多实际间接照明.
  - Considering (more) actual indirect illumination

- Key idea
  - Why do we have to assume uniform incident indirect lighting?
  - Some information of indirect lighting is already known!

    间接照明的一些信息已知
  - Sounds familiar to you?

Screen Space Directional Occlusion

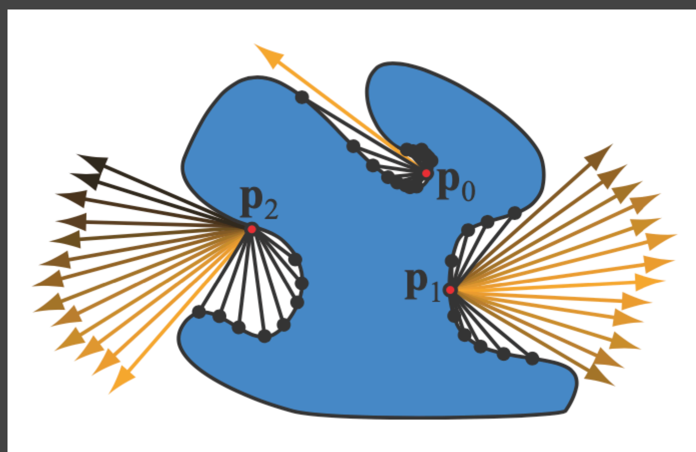
- SSDO exploits the rendered direct illumination
  - Not from an RSM, but from the camera



[Ritschel et al., Approximating Dynamic Global Illumination in Image Space]

Screen Space Directional Occlusion

- Very similar to path tracing
  - At shading point p, shoot a random ray 在着色点，随机投射一条光线
  - If it does not hit an obstacle, direct illumination 如果没有碰到障碍物 则直接照明
  - If it hits one, indirect illumination 如果击中则为间接照明.



[From RTR4 book]

Screen Space Directional Occlusion

- Comparison w/ SSAO

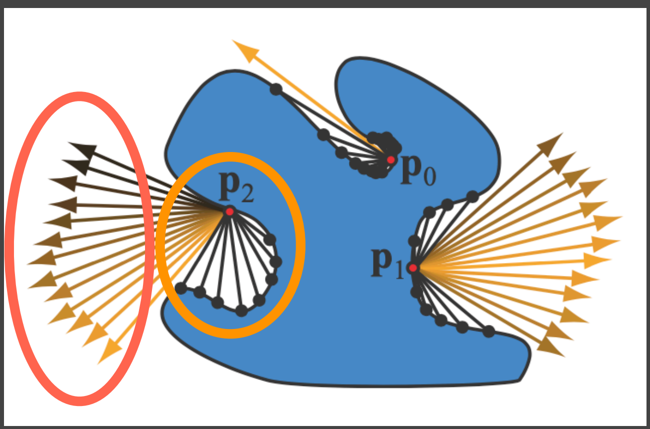
  AO 假设间接光照来自非常远的地方.

  - AO: **indirect illumination** + **no indirect illumination**

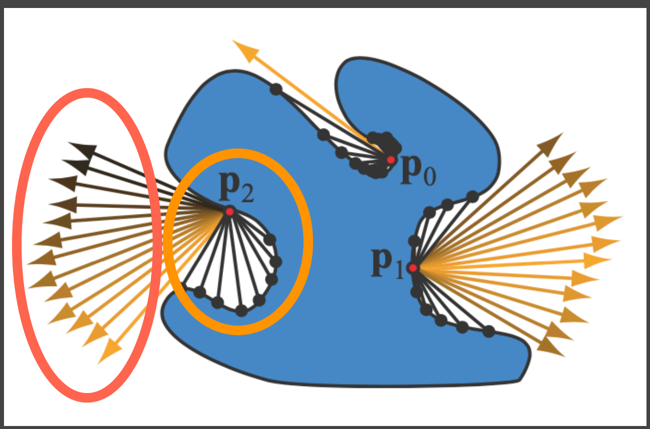
  DO 假设间接光照只来自非常近的地方.

  - DO: **no indirect illumination** + **indirect illumination** (same as path tracing)

[From RTR4 book]



Ambient Occlusion



Directional Occlusion

Screen Space Directional Occlusion

- Consider unoccluded and occluded directions separately

$$L_o^{\mathrm{dir}}(\mathrm{p}, \omega_o) = \int_{\Omega^+, \boxed{V=1}} L_i^{\boxed{\mathrm{dir}}}(\mathrm{p}, \omega_i) f_r(\mathrm{p}, \omega_i, \omega_o) \cos\theta_i \, \mathrm{d}\omega_i$$

可见的，只考虑直接光照。

$$L_o^{\mathrm{indir}}(\mathrm{p}, \omega_o) = \int_{\Omega^+, \boxed{V=0}} L_i^{\boxed{\mathrm{indir}}}(\mathrm{p}, \omega_i) f_r(\mathrm{p}, \omega_i, \omega_o) \cos\theta_i \, \mathrm{d}\omega_i$$

不可见的，考虑间接光照。

- Indirect illum from a pixel (patch) is derived in last lecture

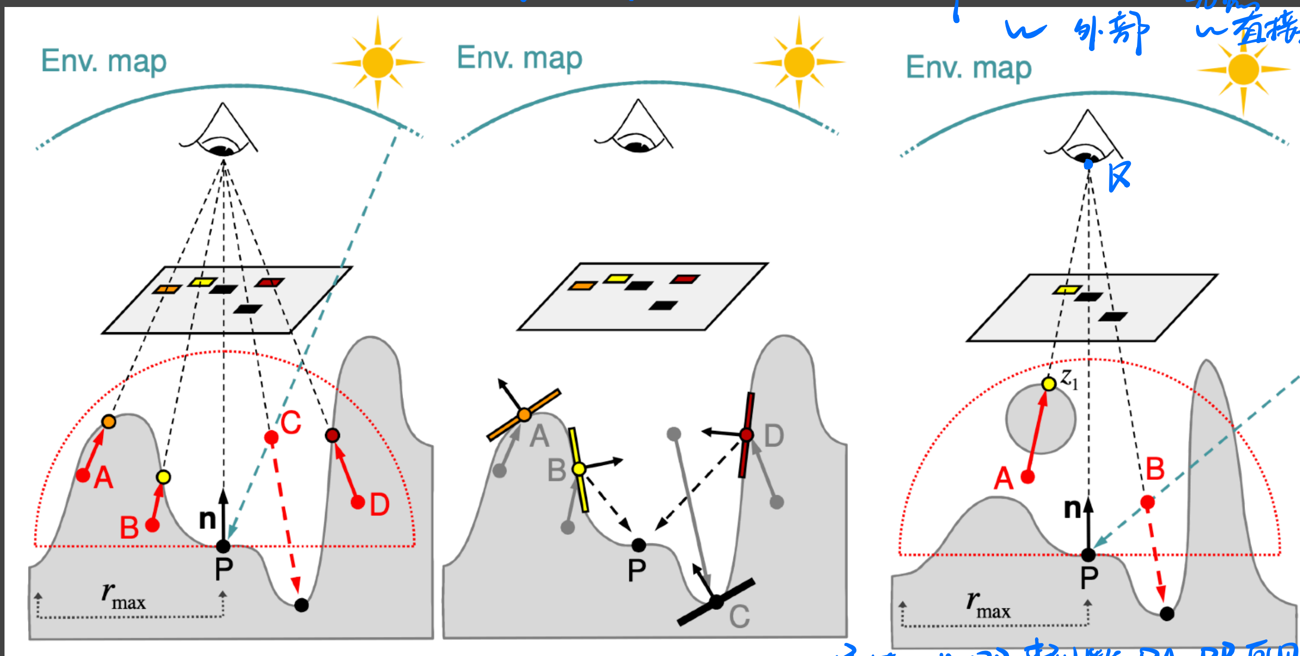
Screen Space Directional Occlusion

- Similar to HBAO, test samples' depths in local hemispheres

与HBAO相似. 测试样本在局部半球的深度.

在物体内部 提供间接光照

~ 外部 ~ 直接光照

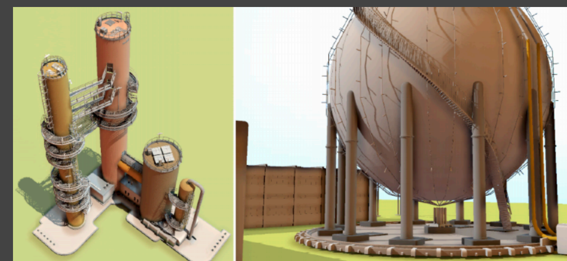


通过以A以B来判断PA,PB可见性 肯定有误差.

Screen Space Directional Occlusion

更接近离线渲染,

- SSDO: quality closer to offline rendering

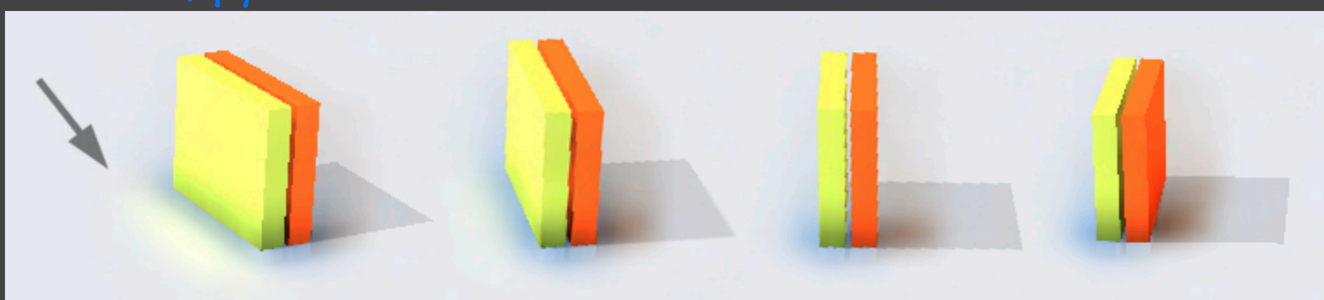


- Issues?

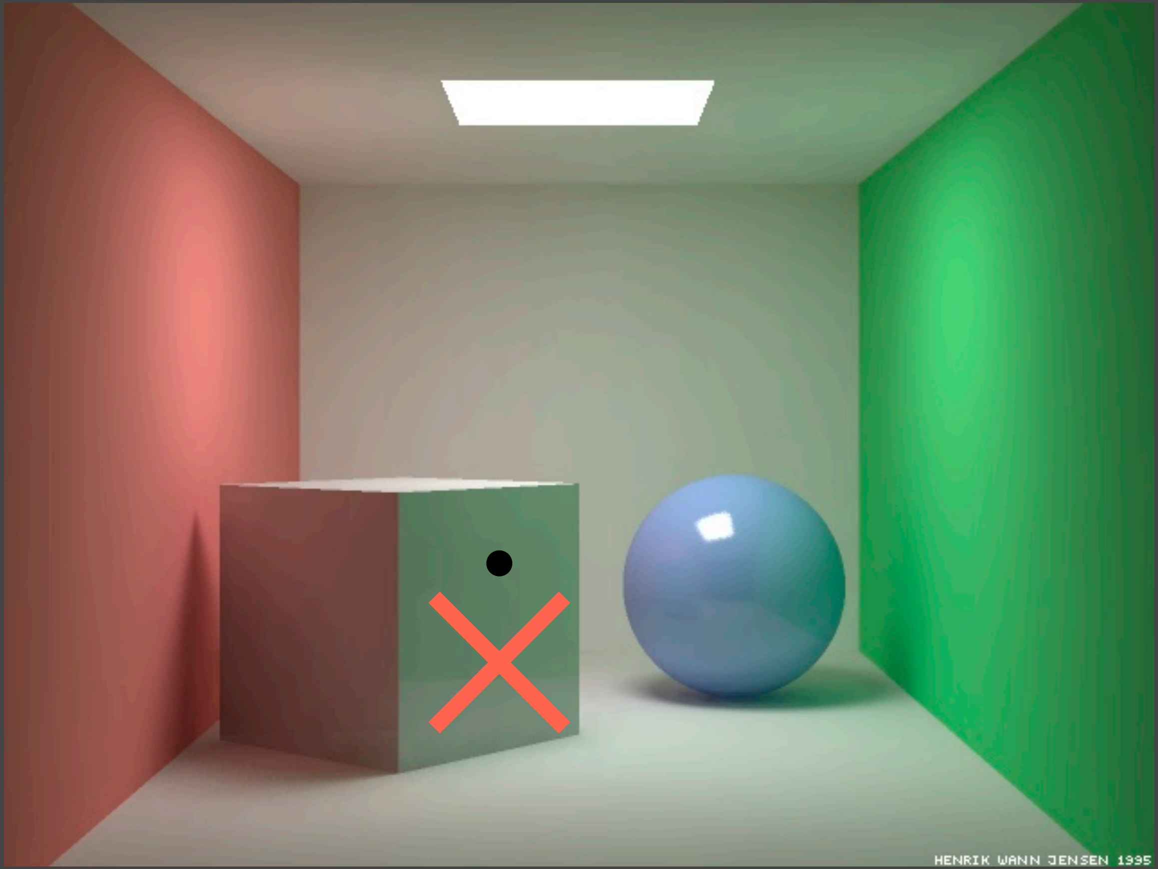
  在一个较小范围内的全局光照

  - Still, GI in a short range
  - Visibility
  - Screen space issue: missing information from **unseen** surfaces

  屏幕空间问题：看不见的表面缺少信息



SSDO: GI in a Short Range



Questions?

Screen Space Reflection (SSR)

(Some slides from SIGGRAPH 2015 course:
Advances in Real-time Rendering)

Screen Space Reflection (SSR)

- What is SSR?

  在RTR中引入全局照明的一种方法。

  - Still, one way to introduce Global Illumination in RTR
  - Performing ray tracing 进行光线追踪
  - But does not require 3D primitives (triangles, etc.)

    但无需3D基元

- Two fundamental tasks of SSR

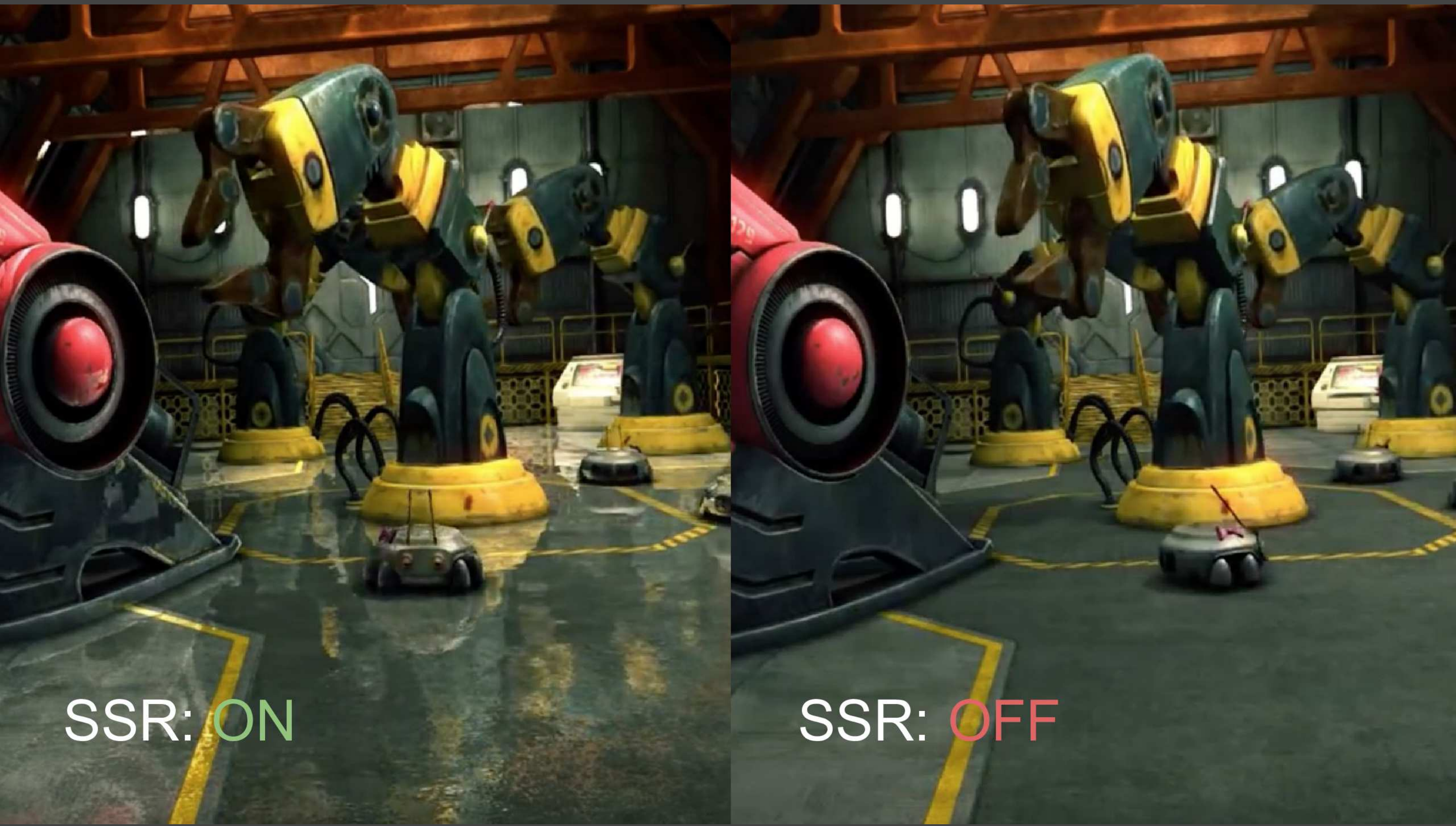
  光线和屏幕空间场景中求交。

  - Intersection: between any ray and the scene
  - Shading: contribution from intersected pixels to the shading point

    相交像素对着色点的贡献。

Screen-space Reflections

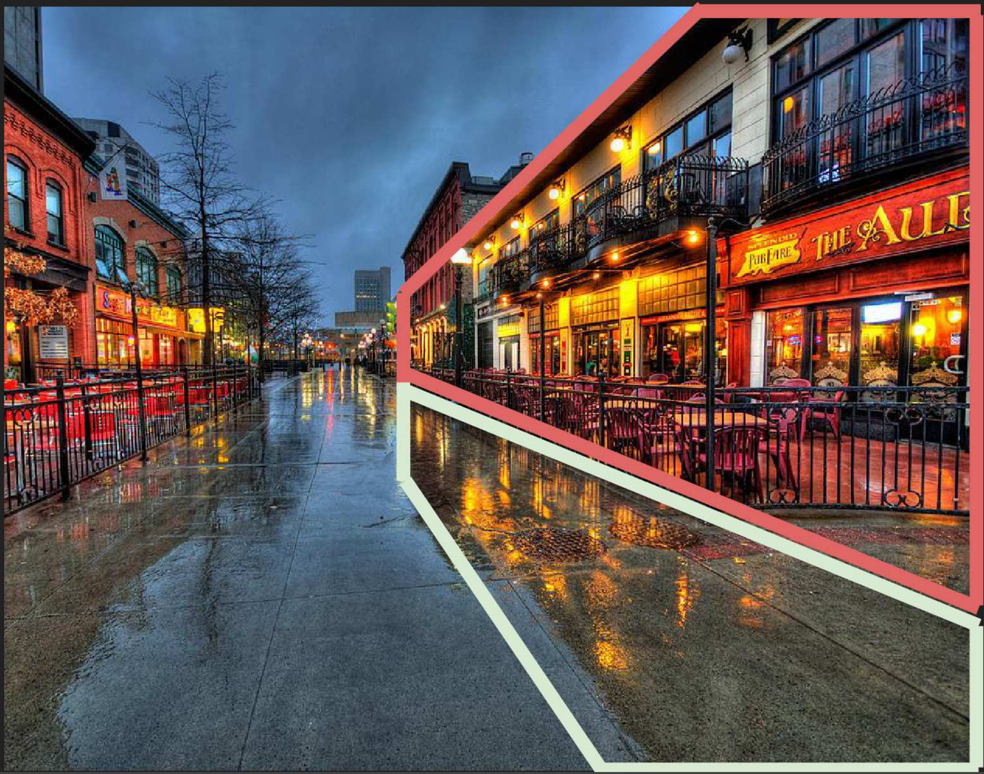
Motivation


SSR: ON
SSR: OFF

What can be exploited in scene?

Reuse screen-space data!

反射光很大程度上反射的是屏幕上已有(已渲染)的东西.

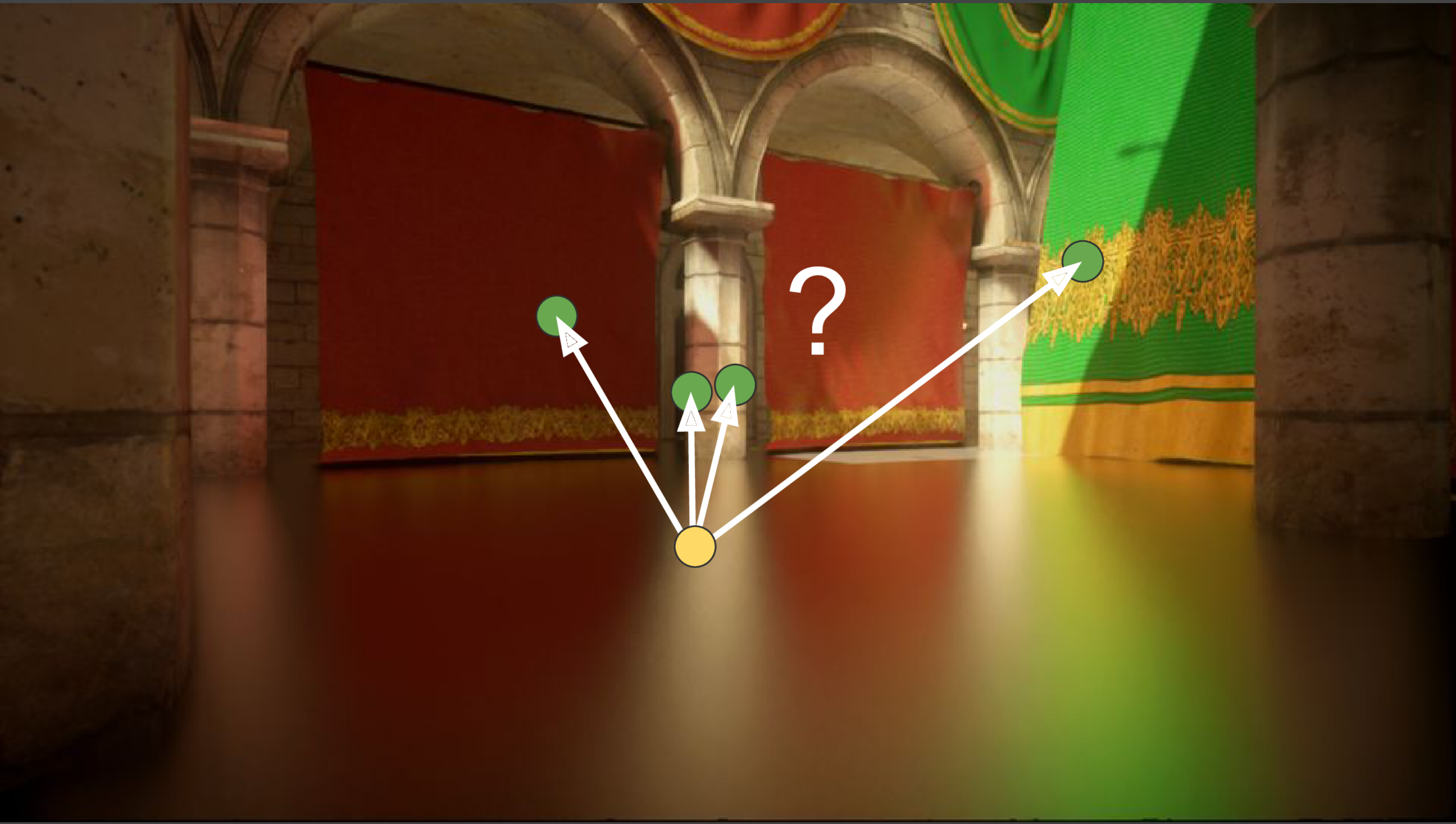


Basic SSR Algorithm - Mirror Reflection

- For each fragment
  - Compute reflection ray
  - Trace along ray direction (using depth buffer)
  - Use color of intersection point as reflection color

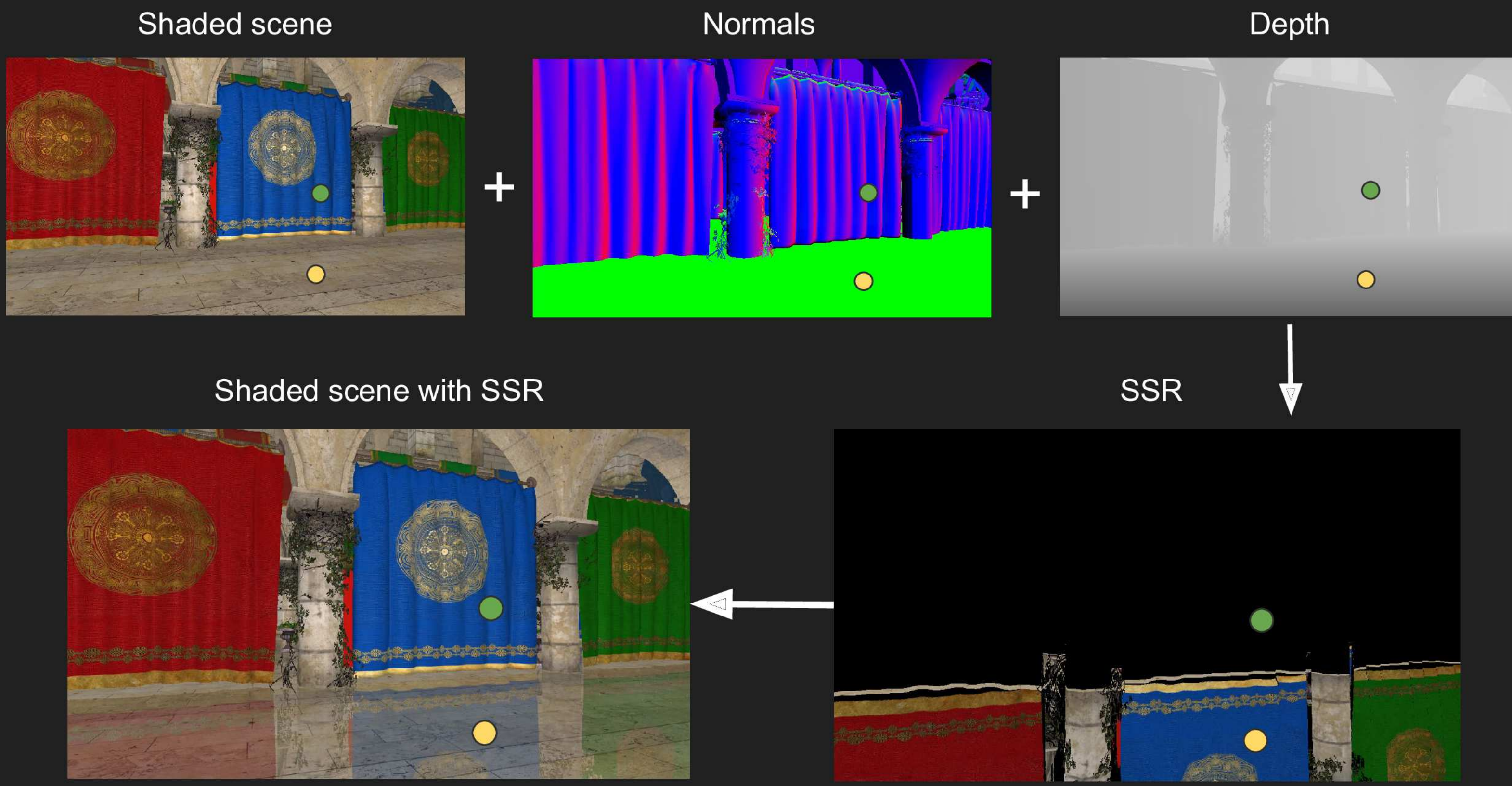
High smoothness

Medium smoothness




Medium smoothness + normals

Variable smoothness


Shaded scene
Normals
Depth
Shaded scene with SSR
SSR

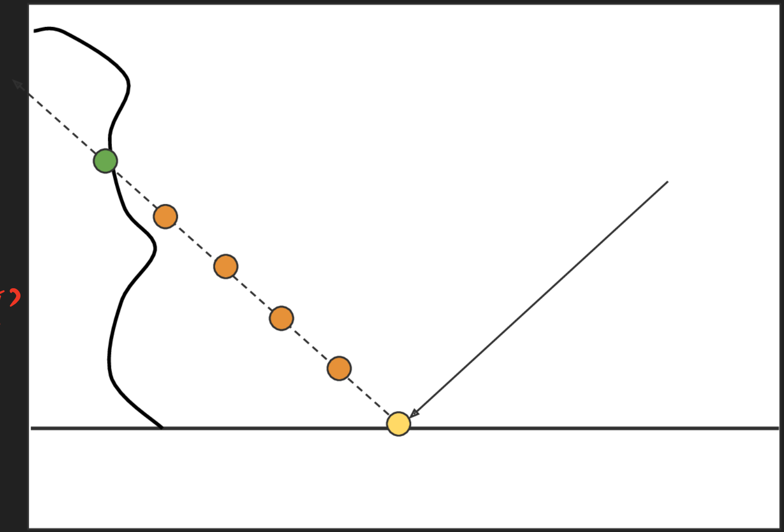
Linear Raymarch

Goal: Find intersection point

- At each step, check depth value
- Quality depends on step size
- Can be refined

1. 每次光线步进，检查其深度值《可见性判断》

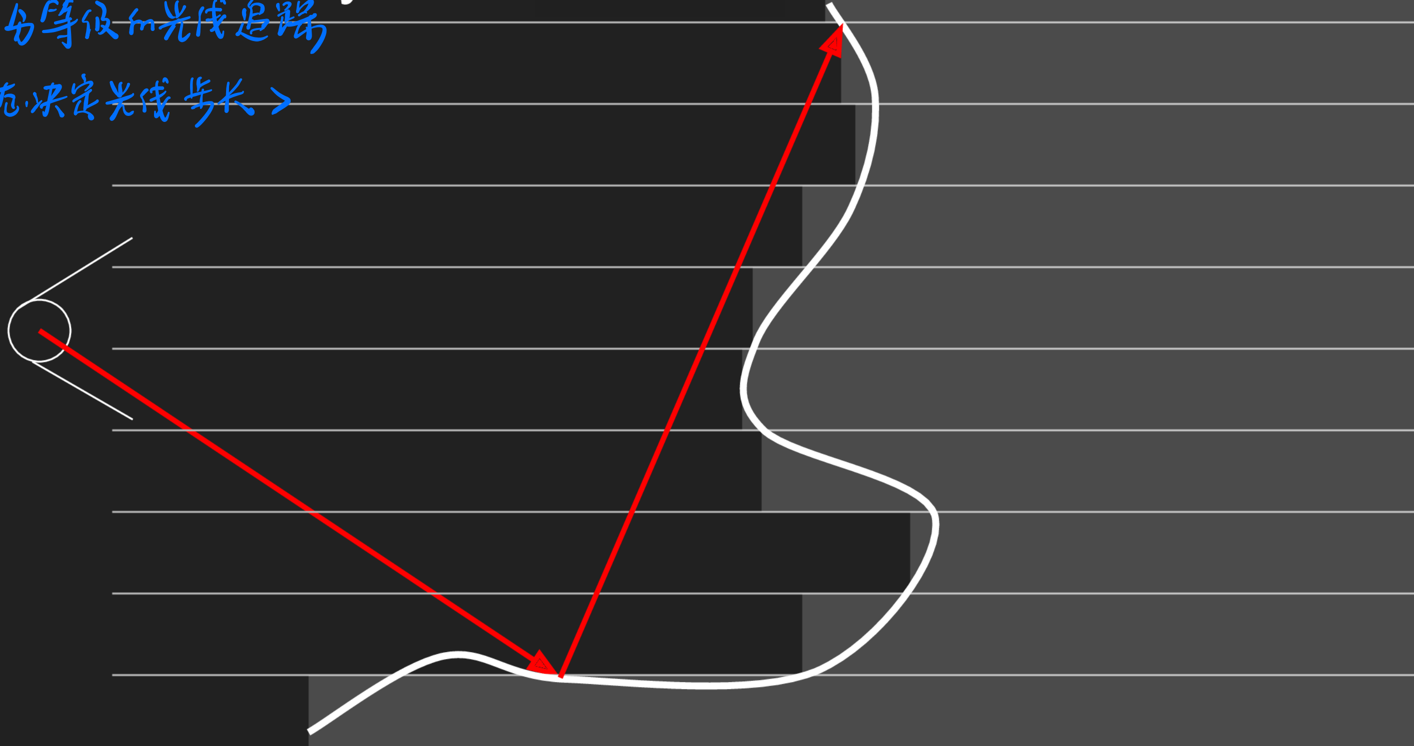
如果深度值 { 小于场景深度 未相交
大于场景深度 相交



Hierarchical ray trace

分等级的光线追踪

<动态决定光线步长>



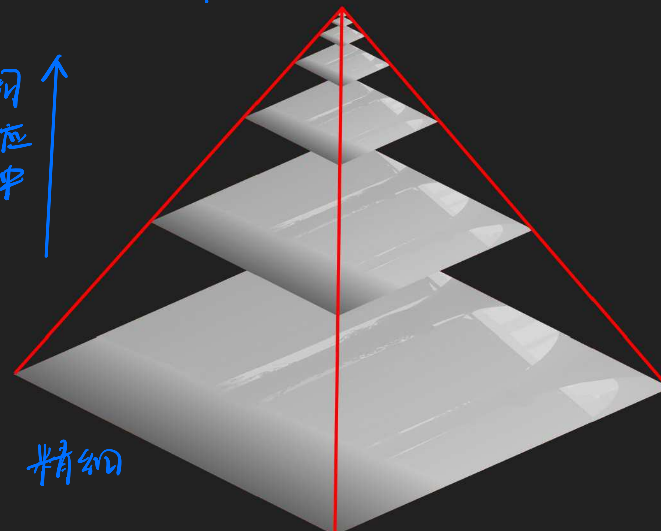
对深度 MIP-MAP

Generate Depth Mip-Map

- Use min values instead of average

不是取平均
而是取对应
N个像素中
最小值.

min-pooling



Why Depth Mipmap

与3D中层次结构<BVH, KD-tree>相似

- Very similar to the hierarchy (BVH, KD-tree) in 3D

可更快地拒绝不相交的捆绑

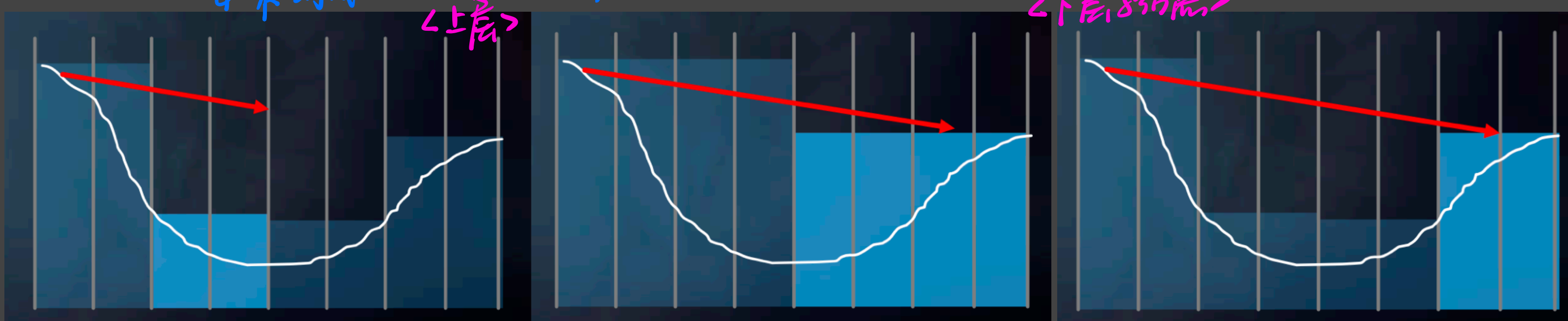
- Enabling faster rejecting of non-intersecting in a bunch

MIN 保证了保守的逻辑.

- The min operation guarantees a conservative logic
  - If a ray does not even intersect a larger node, it will never intersect any child nodes of it

如果射线不与更大的结点相交，则它永远不会与其任何子结点相交.

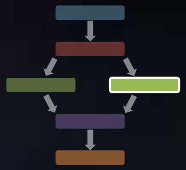
<上层> <下层子结点>



Hierarchical tracing

- Stackless ray walk of min-Z pyramid

```
mip = 0;
while (level > -1)
    step through current cell;
    if (above Z plane) ++level;
    if (below Z plane) --level;
```



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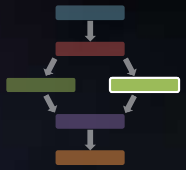
Hierarchical tracing



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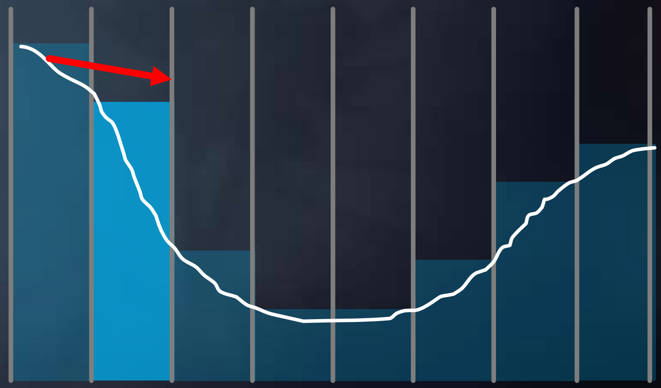

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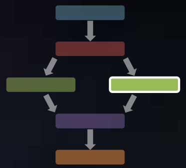
Hierarchical tracing



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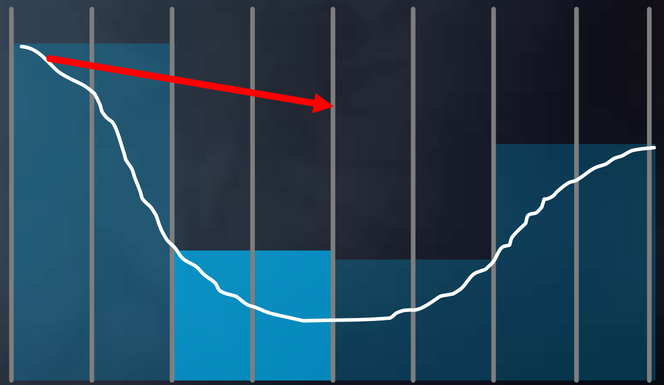

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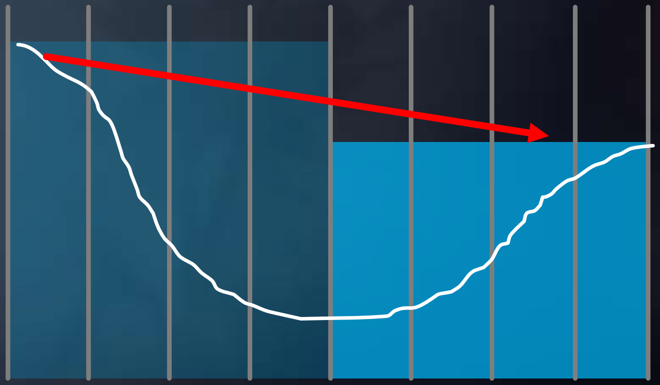

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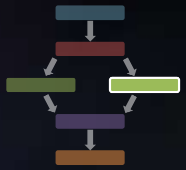
Hierarchical tracing



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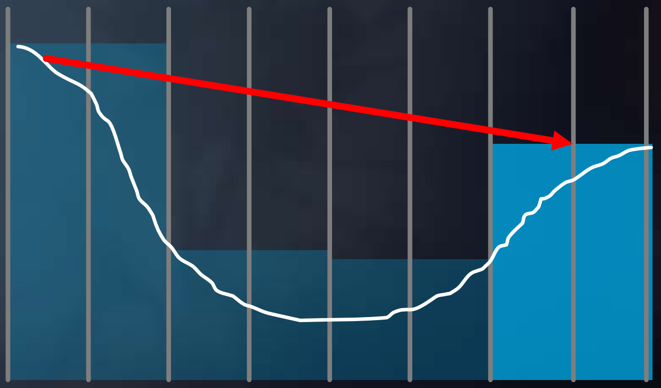

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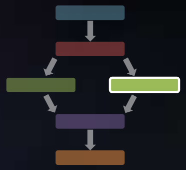

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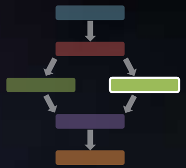

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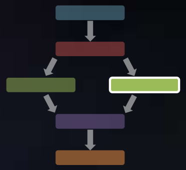

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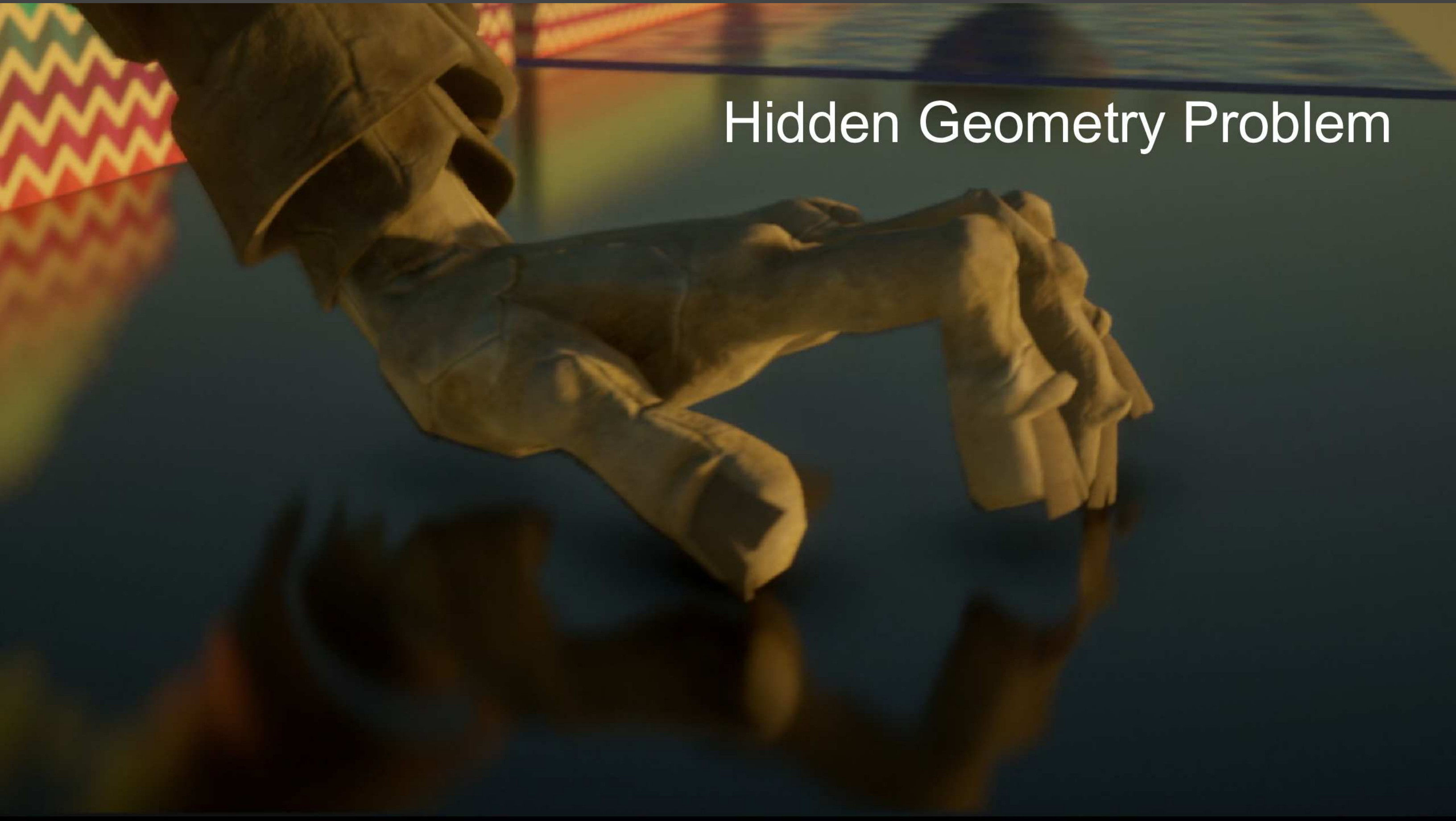
Hidden Geometry Problem


Edge Cutoff

Edge Fading

Shading using SSR

- Absolutely no difference from path tracing

  <因为只知道 q到相机的 radience，不知道 q→p 的 radience）

  - Just again assuming diffuse reflectors / secondary lights

    假设反射物也是 diffuse

$$L_o(\mathrm{p}, \omega_o) = \int_{\Omega^+} \underbrace{L_i(\mathrm{p}, \omega_i)}_{L_o(\mathrm{q},\, q \to p)} f_r(\mathrm{p}, \omega_i, \omega_o) \cos\theta_i \, \mathrm{d}\omega_i$$

- Questions

  不会引入平方距离衰减 < BRDF Sampling>

  - Does it introduce the square distance falloff?
  - Does it handle occlusions between the shading point and secondary lights?

    对 shading point 和次级光源之间遮挡处理很好.

    <每次 ray tracing 找到的 p点都是第1个打到的位置>

Therefore,

Our requirements

specular → glossy → diffuse

trace 光线

少一些　多一点　再多一些.

- Sharp and blurry reflections 清晰/模糊反射
- Contact hardening 接触硬化、
- Specular elongation 镜面伸长
- Per-pixel roughness and normal

每个像素粗糙度和法线

Therefore,

Our requirements

- Sharp and blurry reflections
- Contact hardening
- Specular elongation
- Per-pixel roughness and normal

Therefore,

Our requirements

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Therefore,

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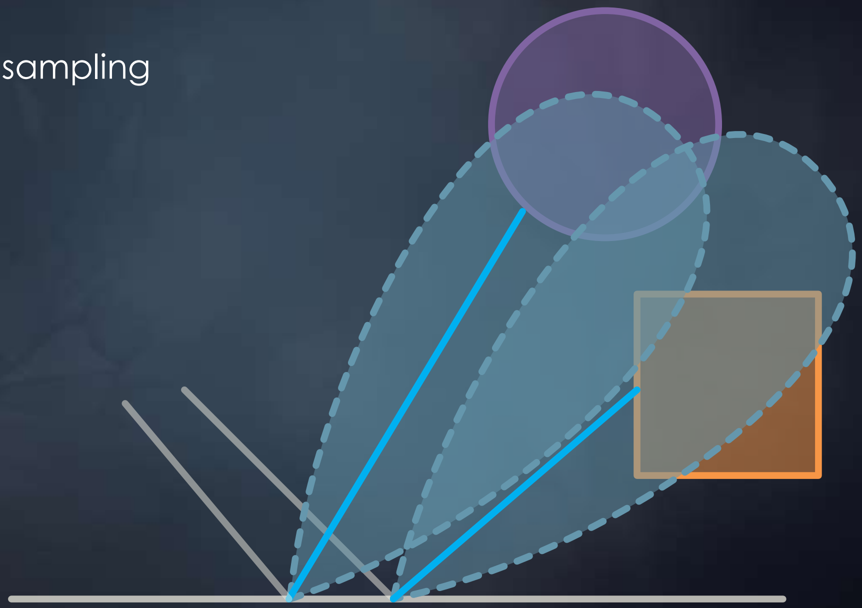
Improvements

Our approach

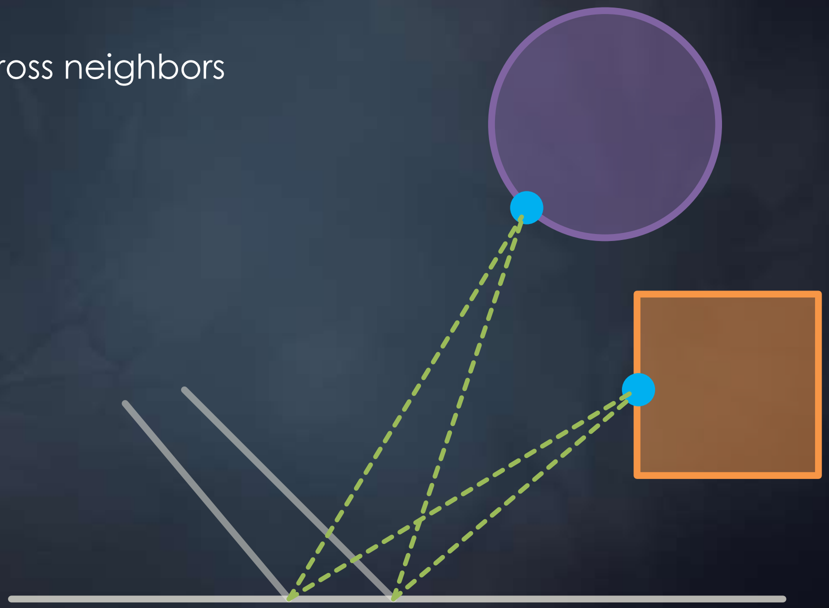
- BRDF importance sampling



Improvements

Our approach

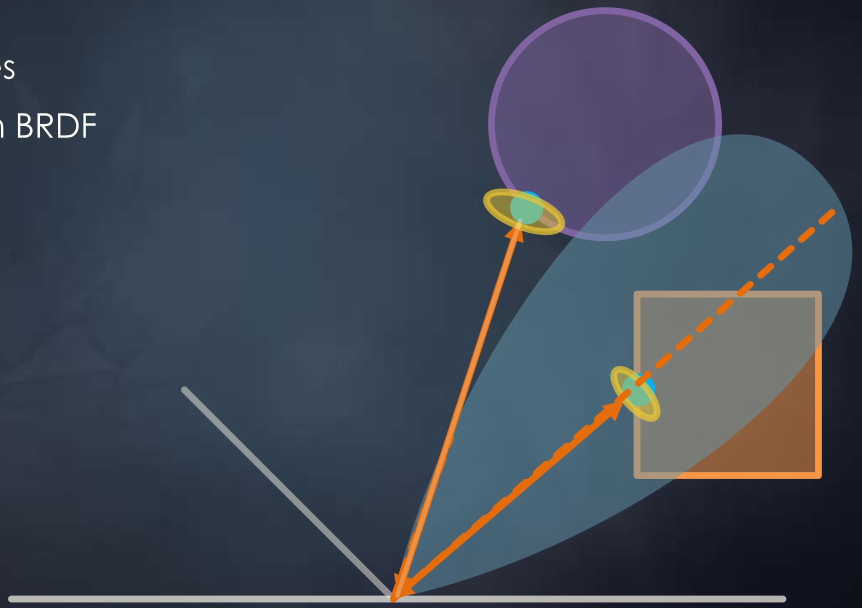
- Hit point reuse across neighbors



Improvements

Our approach

- Prefiltered samples
- Weighed by each BRDF



Summary of SSR

- Pros
  - Fast performance for glossy and specular reflections
  - Good quality
  - No spikes and occlusion issues
- Cons
  - Not as efficient in the diffuse case* 漫反射效率不高
  - Missing information outside the screen 屏幕外缺少信息

Questions?

Next Lecture

- Real-Time Physically-Based Materials

[Big Hero 6, Disney 2014]

Thank you!